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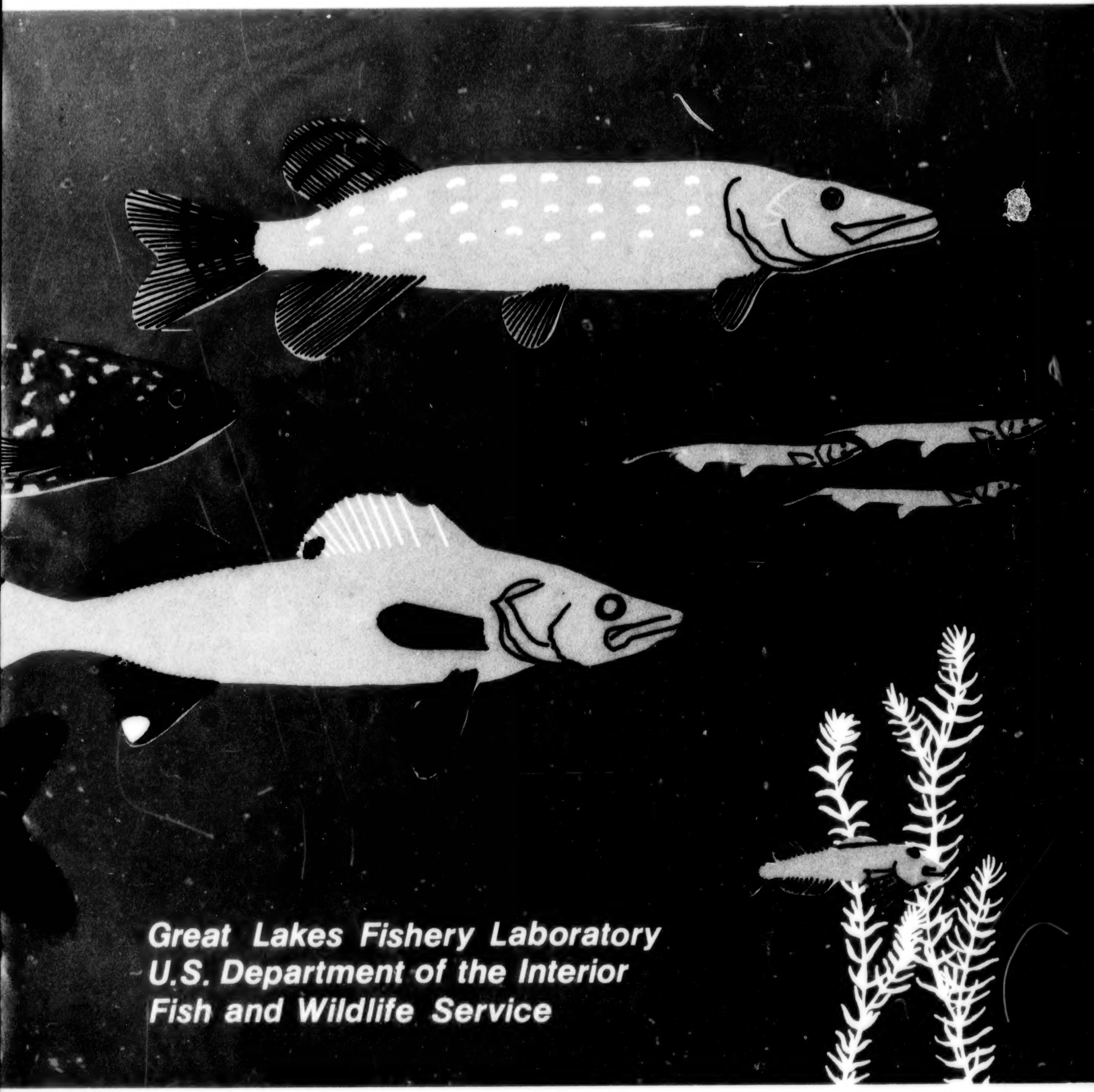
Progress in Fishery Research 1981



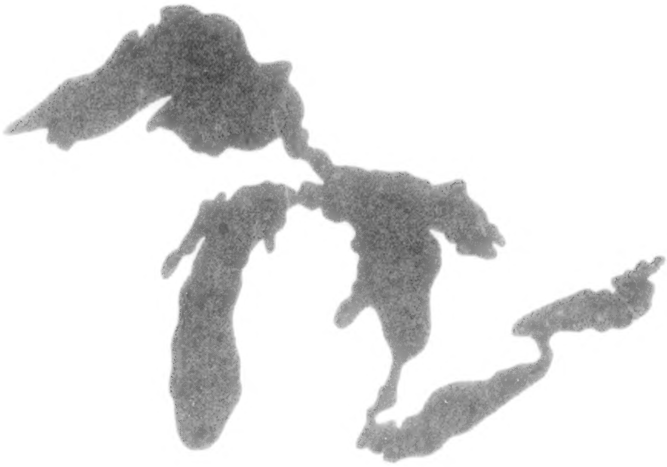
Great Lakes Fishery Laboratory
U.S. Department of the Interior
Fish and Wildlife Service

13 SEP 1982

Great Lakes Fishery Laboratory

U.S. Fish and Wildlife Service
Ann Arbor, Michigan

Progress in Fishery Research 1981



This report does not constitute publication. The results and data presented herein should be considered provisional.
Reference to trade names does not imply endorsement of commercial products.

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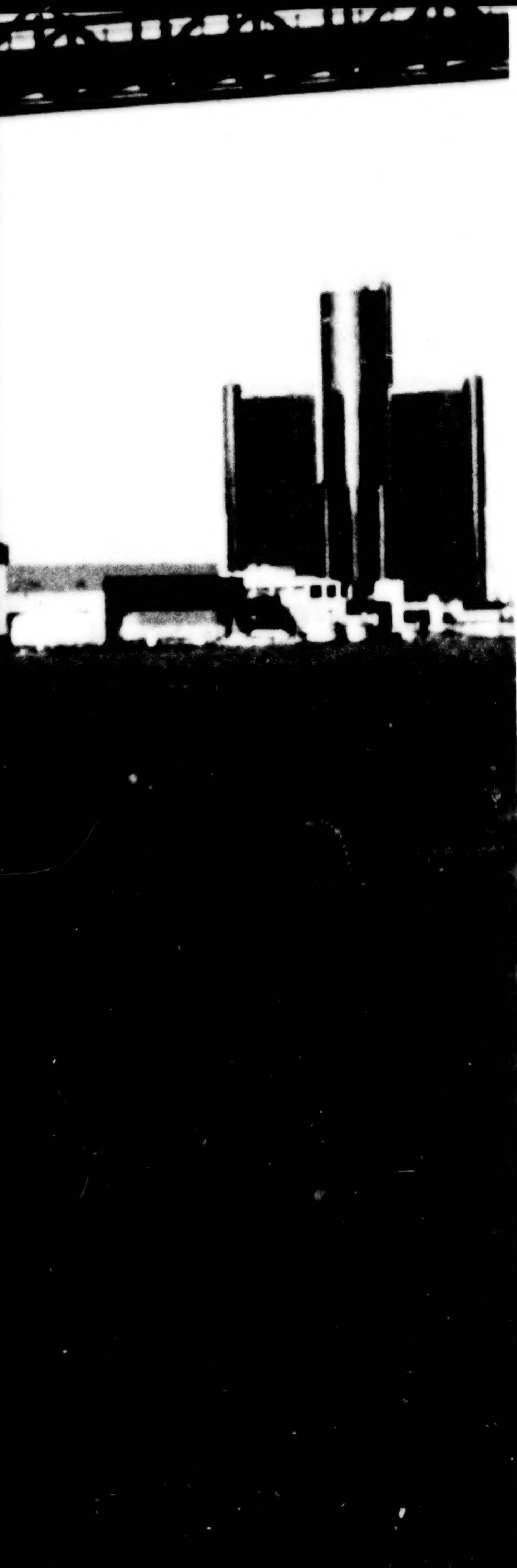


Courtesy of Great Lakes Fishery Commission

Introduction

The Great Lakes—the world's largest body of freshwater—ranks high among the Nation's most valuable natural resources, one that lends an identity as well as substantial economic and aesthetic benefits to an entire region. Nevertheless, we cannot continually take from such a renewable resource without giving it the care and protection vital to its health and productivity. The Great Lakes Fishery Laboratory has been part of this management effort for the past 55 years, conducting fishery research from which a sound scientific basis for the development and implementation of fishery management programs continues to evolve. The success of these programs is reflected in rejuvenation of the Great Lakes commercial and sport fisheries, hence in the livelihood and recreation for millions of people.

In an ecosystem as complex as the Great Lakes, the fishery resource component is inseparable from the whole. The Laboratory coordinates closely with the entire Great Lakes research community to continually expand our understanding of the ecosystem. This requires sustained assessment of the fish populations and looking beyond them to identify other factors in the ecosystem that influence the fishery, such as contamination and other modification of the environment. More than once, the health of fish populations has alerted us to other widespread problems in the Great Lakes ecosystem and has been a gauge in measuring our success at solving them.

Although the fiscal restraints we share with other governmental and research organizations make it imperative that the Laboratory's mission be accomplished as efficiently as possible, we look forward to continuing our key role in fishery research and in offering our assistance in the particularly challenging area of fishery resource management and allocation.

Joseph H. Kutkuhn, Director

Highlights

Some of the more significant observations and accomplishments for 1981 are presented below.

Except in Whitefish Bay in eastern Lake Superior, the abundance of rainbow smelt has decreased sharply in all U.S. waters of Lake Superior since 1978. In some areas, biomass levels in 1981 were reduced by as much as 80 to 95% from those present in 1978. A marked resurgence in lake herring populations suggests that forage stocks, in U.S. waters at least, are reverting in character to what they were in pre-lamprey days, with lake herring and bloaters again providing the bulk of forage for adult lake trout.

The alewife populations in Lake Ontario declined precipitously during the harsh winter of 1976-77 because of low-temperature stress. Since then, an extremely large 1977 and a modest 1978 year-class have been produced, resulting in recovery of this species to levels of abundance approaching those observed before the massive die-off. The condition (K) of mature alewives, which had improved markedly during 1977, has now deteriorated to a level in fall 1981 similar to that observed in fall 1976, just before the die-off.

The condition of fish stocks in treaty-ceded waters was closely monitored. Laboratory staff, together with counterparts in the Michigan Department of Natural Resources and inter-tribal community of Chippewa-Ottawa Indians, spent considerable time during 1981 assessing the condition of (and projecting allowable catches from) stocks of lake trout, lake whitefish, bloaters, lake herring, and several other species in treaty-ceded waters of the Upper Great Lakes. Their draft report was completed in late July, reviewed, approved, and issued in early September 1981.

The fishable stock of walleyes (fish over 14.5 inches in total length) in Lake Erie was projected as 26 million at the start of 1982. Continuing assistance to the Great Lakes Fishery Commission's Lake Erie Committee entailed analysis of biological and fishery statistics collected during 1981 and projection of a total allowable catch of about 5.7 million walleyes for all fisheries in western Lake Erie for 1982.

Despite the resurgence and greatly increased size of western Lake Erie's walleye resource in recent years, analysis of condition factors (K) and other attributes of walleyes sampled in each of three periods—1964-65, 1968-69, and 1976-80—has revealed no marked changes in growth rate.

Preliminary analysis of the diets of yellow perch, white bass, and the very abundant walleyes in western Lake Erie indicates heavy predation, at least by larger fish, on emerald and spottail shiners as well as on other smaller fishes. Survey catches of forage species in spring 1981 were noticeably smaller than in previous years, which may reflect their suppression by predation.

Lake trout of the Lake Superior "lean" strain, stocked in Lake Ontario as fall fingerlings or spring yearlings since fall 1979, continued to demonstrate much higher survival through 1981 than lake trout of the Clearwater Lake (Manitoba) strain. If this differential survival continues to be supported by additional evidence, fishery managers will have to begin questioning the suitability of Clearwater Lake strain lake trout for further introduction into Lake Ontario for restoring self-renewing populations.

Rapid recovery of bloater resources continues in both Lakes Michigan and Huron. Survey catches in 1981 were nearly double those in 1980. Four consecutive strong year classes were produced in each lake, starting in 1977. Another strong year class was produced in Lake Huron in 1981, but only a relatively weak one in Lake Michigan.

Biological oxygen demand may be high enough to impair hatching of lake trout. Preliminary measurements on spawning grounds used historically by lake trout at four locations along a north-south gradient in water quality in near-shore waters of western Lake Huron showed biological oxygen demand of the sediments in Saginaw Bay, where the most eutrophic lake waters were encountered, may be high enough (24 mg/l) to adversely affect hatching success of lake trout eggs.

Criteria was developed for photointerpretation of submersed aquatic macrophytes. Written criteria was developed which, when applied to color aerial photographs of Great Lakes littoral waters at a 1:5000 scale, will permit persons untrained in photointerpretation to distinguish images of beds of submersed aquatic macrophytes and to determine the taxonomic identity of the dominant macrophytes in those beds.

Role of aquatic macrophytes in the feeding ecology of young yellow perch was studied. Analyses of the stomach contents of 440 yellow perch of ages 0–III and of over 1,100 additional samples of invertebrates collected in Anchor Bay, Lake St. Clair, revealed that invertebrates were usually more abundant in macrophyte beds than in macrophyte-free areas, that yellow perch had fed almost exclusively on invertebrates, and that they fed most intensively in areas where the invertebrate prey was most abundant; thus indicating that aquatic macrophytes play an important role in the feeding ecology of young yellow perch in Lake St. Clair.

Behavioral observations of lake trout of the Siscowet, Gull Island Shoal, and Marquette Hatchery strains indicated subtle, yet consistent differences in activity level, fright response, and feeding rate among the three strains.

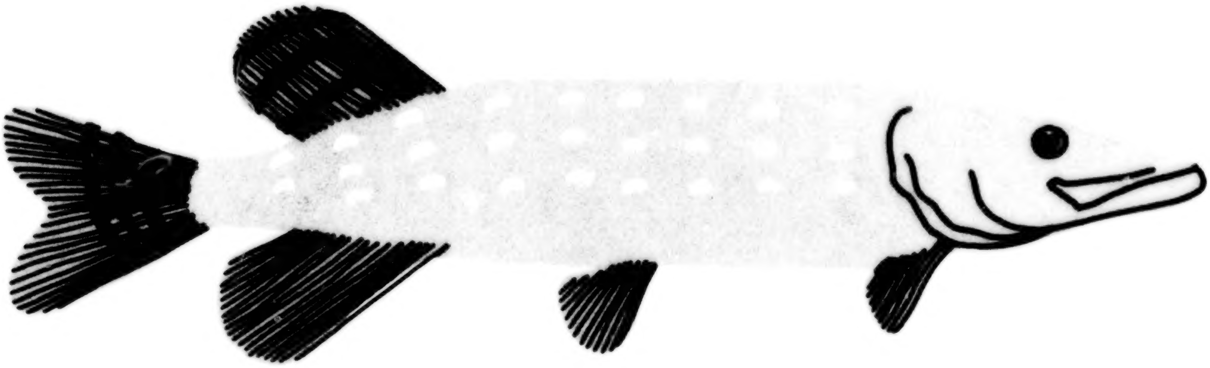
Gas chromatographic/mass spectrometric scans of lake trout or walleyes collected from each of the Great Lakes revealed nearly 500 contaminants, representing more than 15 classes of compounds. Walleyes from Lake St. Clair, followed by lake trout from Lake Michigan, contained the largest number of identified compounds (215 and 167, respectively).

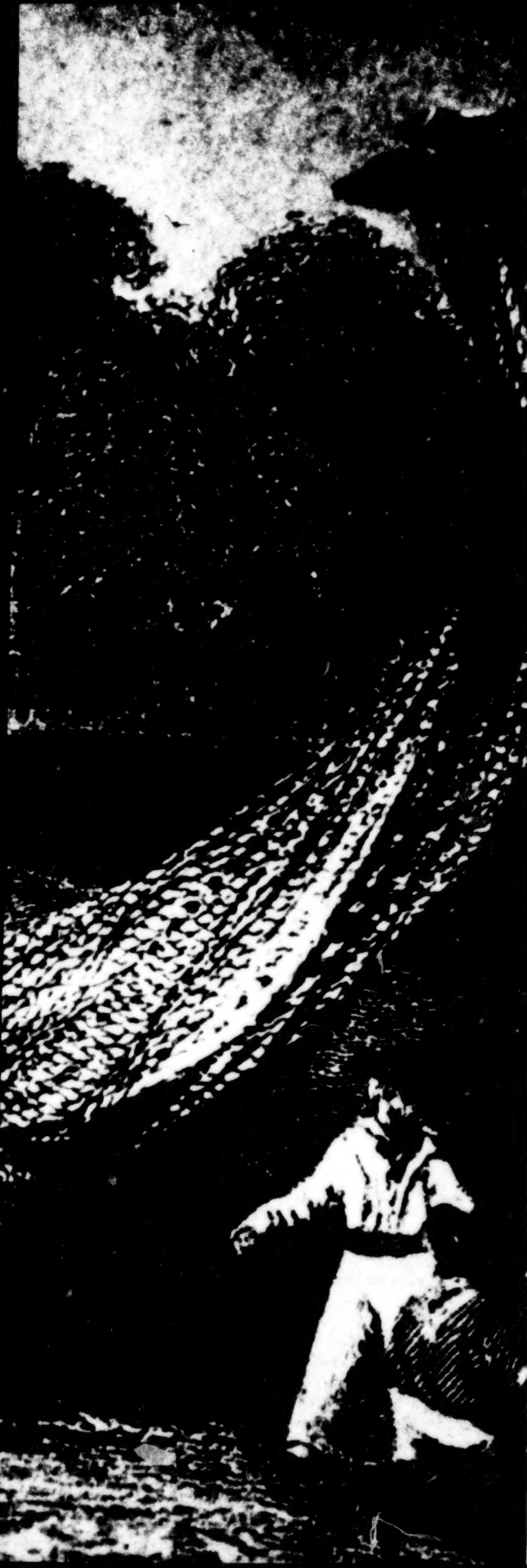
Levels of organic contaminants found to decline in bloaters. Analysis of organic contaminants (PCBs, total DDT, and dieldrin) in bloaters collected from southeastern Lake Michigan during fall 1980 revealed a significant decline in average dieldrin concentration (the first observed during the past 10 years) and continued declines in DDT (95% since 1970) and PCBs (60% since 1974).

Hatching success and fry survival of lake trout varied with the source of the incubation water and the origin of the eggs. Studies on the survival of lake trout eggs and fry in waters of the upper Great Lakes showed that the hatching success of eggs, regardless of source (Lakes Michigan, Superior, or Huron and Marquette Hatchery), was lowest when the eggs were incubated in Lake Michigan water and that of the four sources, eggs from Lake Michigan stocks had the lowest hatching success regardless of incubation site. Fry of Lake Michigan origin suffered nearly total mortality at all rearing sites within 150 days after hatching; overall survival was highest in fry of Lake Superior origin.

Studies on the growth and food conversion efficiency of large lake trout fed natural forage (ad libitum) revealed a marked food preference by the lake trout for smelt over alewives.

Developmental work was completed on a small-scale, flow-through culture and bioassay system for Bosmina and daphnids that allows rapid testing of several contaminants with only minute amounts of each chemical.





Courtesy of Great Lakes Fishery Commission

Resource Assessment

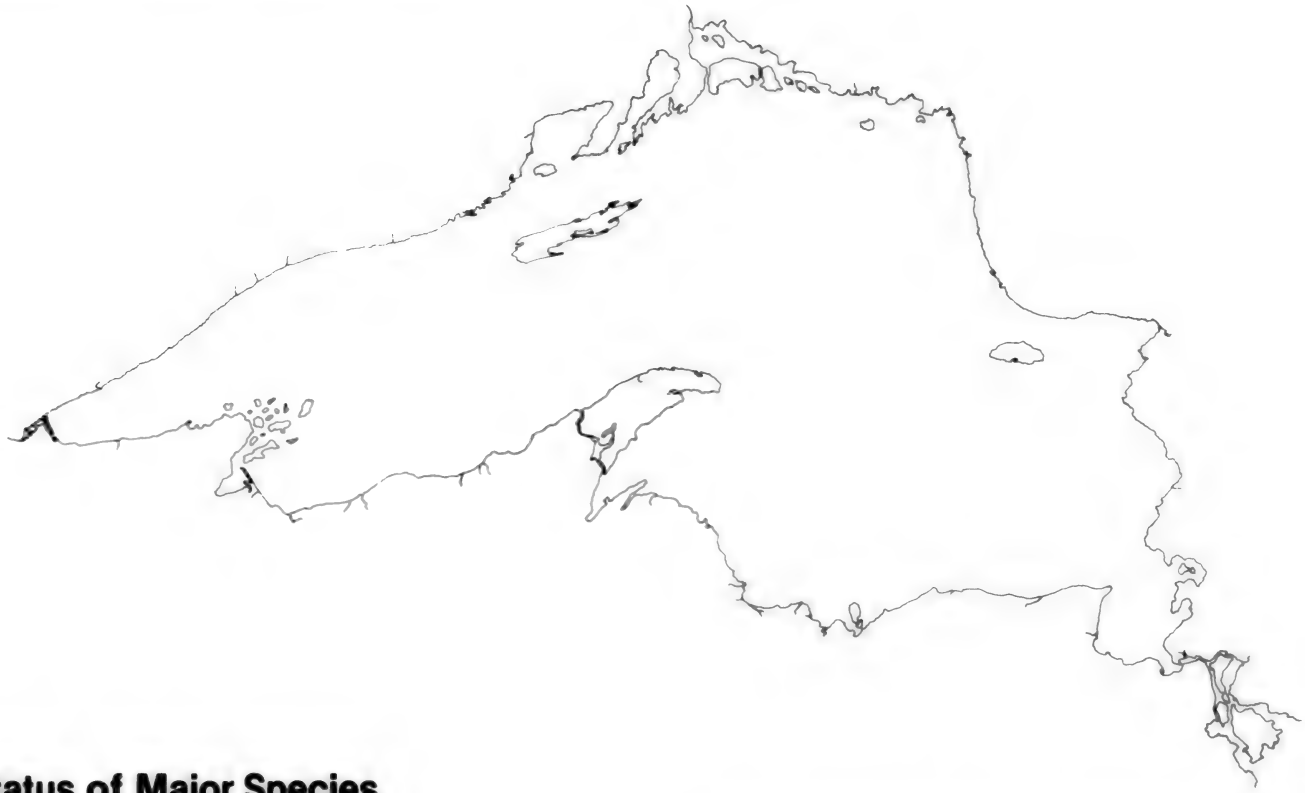
Major fishery resource problems in the Great Lakes are: (1) diminished yields from some populations of important endemic fishes such as the lake herring, bloaters, and yellow perch; (2) incomplete information about the effects of fishing and other mortality agents on stocks of these and other species, especially the lake trout; (3) uncertainty about the size and potential of populations of forage species like the alewife and smelt, whose maintenance is critical to the sustained productivity of salmonid stocks; (4) physical alteration and reduced carrying capacity of nearshore spawning and nursery habitat; (5) underuse of low-value fishes with market potential; (6) the continuing threat posed by the parasitic sea lamprey; and (7) inadequately effective management of fishes based on resources common to two or more political jurisdictions.

In planning and performing its work on these and related matters, this section takes account of the particular mix and priority of problems in each lake, as well as of the special interests and assessment capabilities of each state and provincial agency involved. Major contributions include participation in cooperative lakewide surveys of important sport, food, and forage research on the biology and dynamics of major fish populations; evaluation of sea lamprey control and lake trout restoration programs; and technical assistance in the formulation of interagency management plans.

Wilbur L. Hartman, Section Chief

Lake Superior Fish Stocks

Richard L. Pycha, Project Leader



Status of Major Species

The outstanding features of both experimental trawling and small-mesh gillnetting surveys in 1981 were confirmation of the drastic recent lakewide decline of rainbow smelt, of general stability in the lake whitefish population, and of the sharp increase of lake herring in the western region.

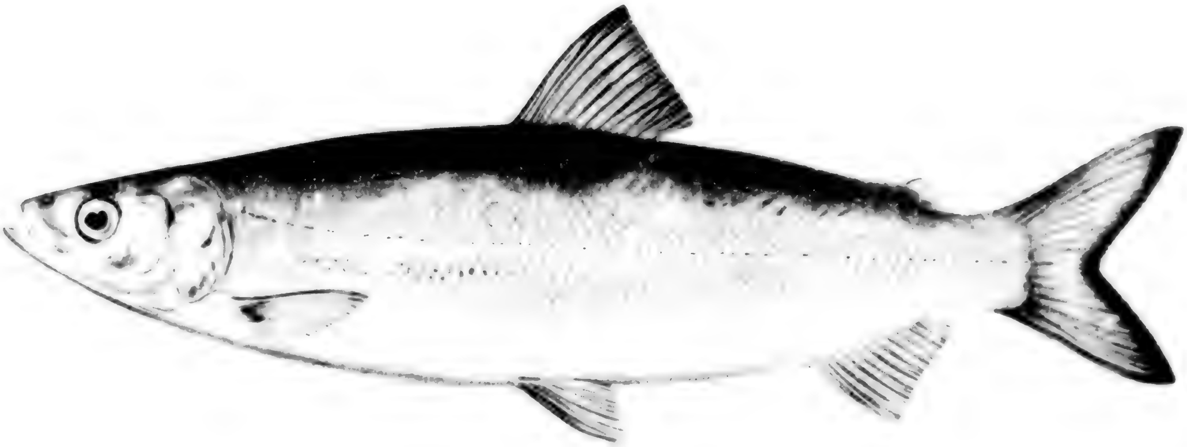
The small-mesh gillnet survey in Michigan waters showed abundance of smelt down 95% from the 1978 level, shortjaw chubs and longnose suckers down 77%, burbot down 63%, bloaters down 58%, and round whitefish down 27%. The only species that did not decline in the catches were lake whitefish (no change) and lake herring (a 78% increase). The 1981 trawl survey in Chequamegon Bay, Wisconsin, produced below average catches of walleyes, yellow perch, white suckers, adult smelt, trout-perch, and emerald, spottail, and mimic shiners. Only yearling lake whitefish and smelt, and splake (stocked in the bay) produced above average catches. Assessment trawling in Wisconsin waters in September and November indicated that the 1981 year class of lake whitefish is weaker than the strong 1978 and 1980 year classes, but is about equal to the 1977-81 average. Since two strong year classes and two of average strength have been produced in the last 4 years, the outlook for lake whitefish in Wisconsin waters appears to be good. Above average catches of both YOY and yearling smelt in the 1981 September-November trawl survey indicates that reproduction has not been reduced despite the recent decline of adults.

Most other forage species produced average to slightly below average year classes in 1981, but catches of YOY alewives were the largest we have ever seen. Alewives have been present in western Lake Superior since mid-1950, but only a few (possibly only two) year classes have been produced that were strong enough to make the alewife anything more than an oddity. The alewife population has remained small and mainly confined to some of the warmer bays. The factor limiting alewives in Lake Superior is unknown, although low temperature is suspected.

Data from experimental trawling in Wisconsin waters west of the Apostle Islands indicated that the 1980 year class of lake herring is by far the largest since we began assessment of this species in 1973. The CPE of yearling juvenile coregonids (mostly lake herring) in 1981 was 15 times larger than the comparable index for the 1978 year class in 1979--and the 1978 year class was itself estimated to be 20 times as strong as the 1973-1977 average. The 1979 year class was weak.

A large commercial fishery on the spawning populations of lake herring was expected in late November and December in Wisconsin because the first of the recent strong year classes (1978) should have been fully mature. However, poor market conditions for lake herring just before the spawning season prevented development of a substantial fishery. The mature population, therefore, was not heavily exploited and should have produced the largest number of eggs deposited in any spawning season for at least 20 years.

Richard L. Pycha
James H. Selgeby
Donald V. Swedberg



Lake Herring

Restoration of Lake Trout Populations

In 1981, as in 1979-80, evidence of substantial natural reproduction of native (not finclipped) fish was widespread in the spring assessment catches. The goal of attaining largely or entirely self-sustaining stocks appears more plausible than at any time in the last 25 years, but it appears that man may be defeating himself. Our data suggests that the positive indicator of progress toward that goal is the status of the progeny of stocks of mature fish that were present 4 to 7 years ago. However, as a result of reductions in stocking rate in the early 1970s and failure to adequately limit exploitation, stocks of mature lake trout have been declining for about 6 years. Even the number of very large fish (84-102 cm total length) has declined for the past 2 years. Although neither the minimum nor the optimum size of spawning stock is known, it is reasonable to assume that the population should have a size and age structure similar to that before the population declined--one that contained a high proportion of large, mature fish several years older than the minimum age for maturity. The population was progressing gradually toward that end in the 1970s, but now appears to be regressing.

In Michigan waters east of the Keweenaw Peninsula, the percentage of native lake trout increased at six of eight spring assessment stations (where large-mesh gillnets were used) and ranged from 32 to 56. The overall percentage of native fish in the catches increased from 37 in 1980 to 39 in 1981. The abundance of native trout as estimated from the spring assessment catch per unit effort (CPE) increased from 1980 to 1981 at five of the eight stations and decreased at three. The sharpest declines in CPE of both native (33%) and finclipped (57%) lake trout were in lower Keweenaw Bay, adjacent to tribal reservation waters where an intense commercial fishery exists. The sharpest rise in abundance of native fish (69%) was at Marquette, and the highest abundance of native fish was at Big Bay, about 30 miles northwest of Marquette. These areas have been closed to commercial lake trout fishing and the Big Bay area is somewhat isolated from all exploitation. Despite the encouraging signs of increased natural reproduction, both of these stations, like all the other Michigan stations, showed some recent degradation in the size and age structure of the population.

A survey with small-mesh gillnets in Michigan waters from Grand Portage to Manitou Island indicated that the abundance of juvenile lake trout (mostly ages II-V) has declined since 1978. The 1981 catch index of 6.4 finclipped lake trout per 305 m of net was 60%

> ***"The goal of attaining largely or entirely self-sustaining stocks appears more plausible than at any time in the last 25 years, but it appears that man may be defeating himself."***

below the 1978 value. Similar assessments in Minnesota waters in 1979 and in Wisconsin waters in 1980 yielded catch indices of 26.0 and 5.0 finclipped lake trout, respectively. Although the 1981 catch index of 4.6 native lake trout in Michigan waters was 36% below the 1978 catch index, it still far exceeded the indices for native fish in Wisconsin (1.0 fish) and Minnesota (0.7 fish) waters of Lake Superior.

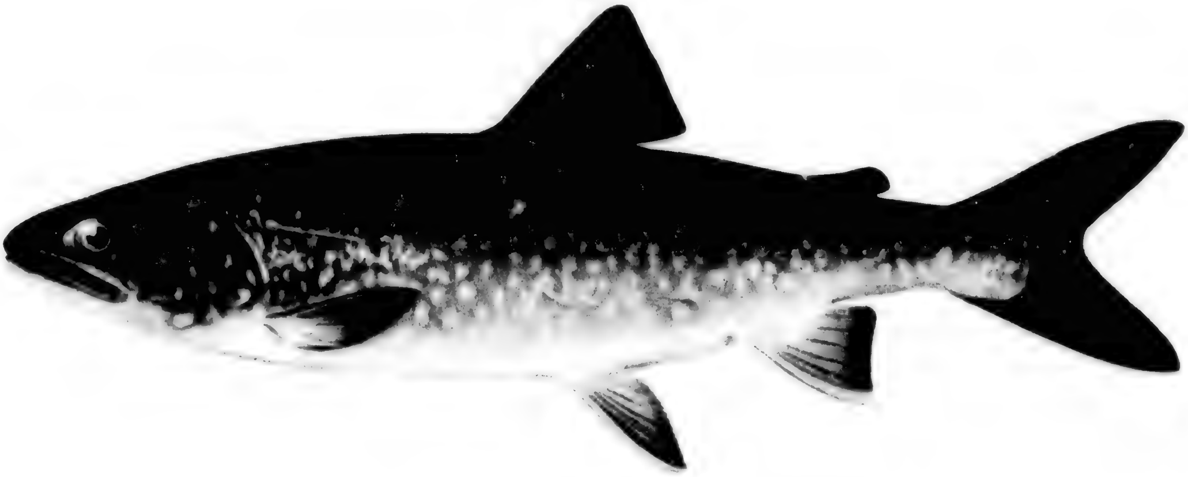
The effects of limiting exploitation were clearly shown by an analysis of changes in abundance (in Wisconsin waters) of large, but not necessarily mature, lake trout at spring assessment stations, and large, mature lake trout on spawning reefs in October, within and outside a large refuge closed to all fishing. From 1970 to mid-1975, exploitation (both sport and commercial) increased in most of the waters among the Apostle Islands, but remained low in the open waters east of Gull and Michigan Islands. Abundance of large lake trout declined over 60% among the Apostle Islands, but increased about 40% east of Gull and Michigan Islands. The number of spawners taken on spawning reefs declined over 80% among the Apostle Islands, but increased about 20% east of Gull and Michigan Islands. In mid 1975, the sport, commercial, and Indian tribal fisheries converged on the formerly lightly fished area. By October 1975, the abundance of lake trout spawners on Gull Island Shoal, the largest spawning area in Wisconsin's waters, had declined 50% from the 1974 level. A large refuge east of the Apostle Islands encompassing the Gull and Michigan Island spawning grounds was established by an emergency order of the Governor of Wisconsin and the refuge has been closed to all lake trout fishing since then.

The amount of natural reproduction appears to be strongly and positively related to abundance of spawners, and abundance of spawners is strongly and negatively related to exploitation. Since the refuge was established, the abundance of spawners on the reefs therein has quadrupled and abundance of 5 to 6-month-old native progeny at index trawling stations nearby has increased over 60-fold. Even though abundance of spawners has tripled in areas outside the refuge as a result of three large plants in 1974-76, it is less than one-tenth the level within the refuge; furthermore, no evidence of any substantial number of native young-of-the-year (YOY) lake trout has been found outside the refuge, even though a few native young have been taken nearly every year since 1968.

> ***"...as a result of reductions in stocking rate in the early 1970s and failure to adequately limit exploitation, stocks of mature lake trout have been declining for about 6 years."***

Sea lamprey wounding rates on lake trout in spring assessment catches in Michigan waters declined somewhat from 1980 to 1981, but the average rate for all areas was still slightly higher than in 1974 and

Lake Trout



1979, the years of lowest wounding. Two areas, Munising and lower Keweenaw Bay, had much higher wounding rates than other areas in Michigan, for the second year in succession. Intensified surveys of streams have revealed no significant sources of sea lamprey escapement near these areas. High predator-prey ratios caused by reductions in the lake trout population may account for the high wounding rates in these two areas.

Wounding rates in Minnesota waters continued the generally downward trend of the last 7 years, but were still roughly 50% higher than in Michigan waters. In Wisconsin waters, where wounding rates were the lowest in the lake for over a decade, wounding increased in both 1980 and 1981. Wounding rates in 1981 in Wisconsin waters were slightly below those in Michigan waters among fish less than 63.5 cm and were substantially higher than in Michigan waters among fish longer than 63.5 cm.

A study of population characteristics of native lake trout at Stannard Rock (eastern Lake Superior) during the decline and recovery of that stock was begun in an effort to determine characteristics necessary for rehabilitation. Analysis of scale samples collected during 1959-65 indicates that lake trout from this offshore area (30 miles from shore) grow slower--by as much as 1 to 2 inches per year--than do nearshore fish. However, intense sea lamprey predation in 1955-61 may have caused size-selective mortality of the larger, faster-growing fish that would lead to low estimates of average growth increments. Differences in diet may also be a factor. Stomach analyses of 60 Stannard Rock lake trout taken in July 1981 indicated that the bulk of the diet consisted of lake herring among large fish and mysis among smaller fish; in contrast, lake trout feed almost exclusively on smelt in inshore waters. Examination of maturity data collected in 1980 and 1981 indicated that female lake trout from Stannard Rock mature at a smaller size than do those inshore. Slower growth and smaller size at maturity could result in higher survival in the presence of size-selective sea lamprey predation.

Richard L. Pycha
Donald V. Swedberg

Distribution, Abundance, and Productivity of Forage Fishes

Abundance of smelt in U.S. waters of Lake Superior declined sharply again in 1981, as it did in 1980. Total biomass of smelt available to trawls was estimated to be only 181 metric tons (t), as compared with 3,231 metric t in 1978, 1,964 metric t in 1979, and 620 t in 1980. Lakewide smelt biomass was only about 5.6% of that recorded in 1978 (3.1% in Minnesota, 5.4% in Wisconsin, and 6.3% in Michigan).

In Whitefish Bay, Michigan, estimated smelt and sculpin biomass was about the same as in 1980. Whitefish Bay was the only area in U.S. waters of Lake Superior where forage stocks did not decline from 1980 to 1981, although levels of smelt biomass in both years were only about 10% of that level recorded in 1978. The biomass of smelt in Whitefish Bay in 1981 was 2-1/2 times larger, on an areal basis (kg/ha), than in other areas of the lake; slimy sculpin biomass was 20-30 times greater than in other areas of the lake.

In the Apostle Islands region of Wisconsin where data series are continuous since 1974, estimated biomass of smelt peaked at 2,000 metric t in 1977 (smelt there made up 86% of the total biomass of the six major forage species--smelt, three species of sculpins, trout-perch, and ninespine sticklebacks). Estimated smelt biomass in 1981 was only 58 t, or about 3% of that in 1977, and total forage biomass was 349 t, down 85% from the 2,330 t in 1977. In addition to the major decline in smelt biomass, that of sculpins declined from 314 t in 1977 to 91 t in 1981.

There is no clear explanation for the sharply declining levels of forage stocks. The substantial declines of smelt biomass are not due to year-class failure but are the result of greatly increased mortality among older fish. By mid- to late 1981, almost all the smelt taken in sampling gear were yearlings. Although the relatively high levels of forage biomass in Whitefish Bay are associated with the lowest levels of predator fish in all areas of Lake Superior, the forage stocks there have declined substantially during a period when predator stocks have also declined. No evidence of an epidemic die-off has been found. Although the decline in smelt abundance is lakewide in Lake Superior, it has not occurred in Lake Huron, even though Lake Huron is directly connected to Lake Superior by the St. Marys River. Whether the declines in smelt stocks will continue, and what effect the documented declines will have on the well-being of predator fishes, are matters of considerable concern.

James H. Selgeby

Lake Michigan Fish Stocks

LaRue Wells, Project Leader

Status of Major Species

Bloaters--The abundance of adult bloaters increased in 1981 for the fourth consecutive year. Catches exceeded those in 1980 at each of the eight localities visited during our regular fall survey (Table 1); average catch at all stations combined was well over twice that of 1980. The steadily increasing abundance of bloaters has resulted from the production of relatively strong year classes each year in 1977-80. However, the 1981 year class appears to be considerably weaker; the catch of YOY bloaters in 1981 all stations combined was only about 67% of that in 1980.

Alewives--After a severe decline in 1980, the abundance of adult alewives rebounded sharply in 1981. Catches in our fall survey were up substantially at six stations and about the same as in 1980 at two stations (Table 2). The combined average catch at all stations was more than 2.5 times that of 1980. Young-of-the-year alewives increased even more than did the adults, judged by the four-fold increase over 1980 in the combined survey catches; however, catches of these young alewives are strongly influenced by weather conditions, so the catches are not always dependable indices of abundance.

Yellow perch--Our standard summer gillnet survey indicated that yellow perch in southeastern Lake Michigan increased moderately in abundance from 1980. The increase is attributable mainly to an influx of 2-year-olds, suggesting that the 1979 year class of perch is considerably stronger than average.

Deepwater sculpins--After having increased steadily and spectacularly (from very low levels) for nearly a decade, the abundance of deepwater sculpins turned abruptly downward in 1981. Combined catches in the fall trawling were only about half those of 1980. The decline may have resulted from a winter die-off. We collected many dead deepwater sculpins from the deeper sampling locations in spring 1981.

LaRue Wells
Sherell C. Jorgenson

Table 1. Average numbers of adult bloaters caught per 10-minute tow in fall at eight index stations in Lake Michigan, 1973-81.[a]

Location	1973	1974	1975	1976	1977	1978	1979	1980	1981
Benton Harbor	2	4	7	7	4	2	14	63	88
Saugatuck	2	4	5	1	4	50	91	111	352
Ludington	30	9	8	4	2	24	106	280	434
Frankfort	63	8	9	2	1	30	140	47	400
Manistique	5	2	3	5	5	4	13	45	169
Sturgeon Bay	1	2	0	1	1	2	7	7	70
Port Washington	2	5	3	b	2	5	39	126	194
Waukegan	3	4	4	2	2	11	37	171	238
Average (stations combined)	12	4	5	3	2	14	50	94	243

[a] Tows at each station were made at 9-m intervals from 18 to 90 m.
[b] Not sampled.

Table 2. Average numbers of adult alewives caught per 10-minute tow in fall at eight index stations in Lake Michigan, 1973-81.[a]

Location	1973	1974	1975	1976	1977	1978	1979	1980	1981
Benton Harbor	413	458	492	113	117	128	81	303	295
Saugatuck	243	391	173	127	141	137	48	59	293
Ludington	784	360	128	274	103	97	98	26	330
Frankfort	1669	44	1244	229	123	154	315	44	163
Manistique	73	11	121	217	315	83	492	60	613
Sturgeon Bay	187	174	113	138	205	1198	1711	221	516
Pt. Washington	143	299	378	b	197	293	200	146	452
Waukegan	441	567	999	360	212	278	255	305	310
Average (stations combined)	494	288	406	194	177	296	400	146	371

[a] Tows at each station were made at 9-m intervals from 18 to 90 m.
[b] Not sampled.

Restoration of Lake Trout Populations

As our contribution to the annual lakewide interagency assessment of lake trout stocks in Lake Michigan, we surveyed lake trout populations off Saugatuck and Port Washington in September 1981. We also sampled lake trout at Saugatuck in December to gather information on their early winter depth distribution and diet.

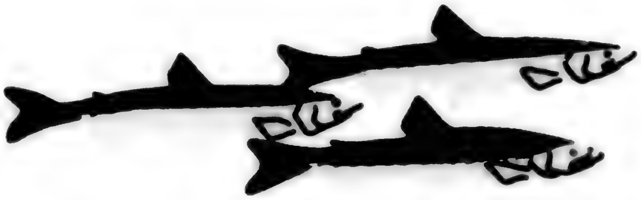
In the fall survey at Saugatuck, we caught 576 lake trout in 25 overnight sets of standard gillnets (each 240 m long). The catch comprised 512 fish stocked lakewide as yearlings in spring 1967-81; 55 planted as fingerlings in fall, mostly at Grand Haven in 1971-75; and 9 for which origin could not be determined (due to finclip abnormalities). The overall catch per net night (23) was similar to those in each year from 1976 to 1980 (range 22-27). Among the fish stocked in spring, the 1976 planting, which contributed 31% of the total, was by far the best represented in the catches.

At Port Washington, we took 450 lake trout in 12 overnight sets of standard gillnets. The catch included 420 planted as yearlings in spring 1967-80; 20 stocked as fingerlings in fall, mostly at Milwaukee in 1972-73; and 10 for which stocking history could not be determined. The CPE (37) was slightly (but probably not significantly) less than in 1979 and 1980 (41 each year). The plantings of 1975, 1976, and 1977 contributed most to the catches of spring-planted fish, making up 19, 15, and 15% of the total respectively.

In our 1981 December sampling at Saugatuck, the CPE of lake trout (26) was not greatly different from that in September. However, fish were abundant at greater depths in December. The shift in depth distribution was most prominent among large fish, which, when compared with smaller fish, were generally in shallower water in September but in deeper water in December. The change in the relation between depth and fish size probably resulted from thermal changes. Water temperatures decreased with depth in September but increased with depth in December, and large lake trout are known to generally prefer warmer water than preferred by smaller ones. The trout caught in December had eaten mostly alewives, but some had fed on smelt, a few on bloaters, and others on slimy and deepwater sculpins.

Results of limited sampling at the Sheboygan Reef (near mid-lake, off Port Washington) in late October 1981 suggested that only a small portion of the lake trout of the Green Lake strain stocked on the reef in 1976 remained there. We caught considerably fewer per unit of effort than in 1980, and far fewer still than in 1979. (The Green Lake fish, descendants of deep-spawning populations native to southern Lake Michigan, were stocked on the reef with the hope that they would eventually spawn there and have a better chance of reproducing successfully than lake trout planted near shore.) Several of the Green Lake fish were taken near shore at Port Washington and Saugatuck in September 1981. The four fish caught on the reef were 508 to 574 mm long, and none were mature; most of the 14 caught near shore were more than 600 mm long, and all but one were mature. The slower growth and maturation of the fish on the reef undoubtedly results from exposure to the deeper, colder water there than near shore. Since the sampling on the reef was conducted during the spawning season, and no spawners were taken, it seems likely that few if any of the fish that left the reef returned there to spawn. However, any fish that remain on the reef until they reach maturity (probably in 1982 for most) might well spawn there.

LaRue Wells
Sherrell C. Jorgenson



Population Biology and Potential Yield of Lake Whitefish

Although sampling was curtailed during 1981 due to budgetary limitations, the data we did collect suggested that lake whitefish in east-central Lake Michigan were generally most abundant at depths of 18-22 m. Samples from standard gillnets (mesh sizes, 6.4 to 13.2 cm by 1.27-cm increments) fished in late summer and early fall contained whitefish ranging in age from I to XII, and in length from 284 to 722 mm; however, only 41% were older than age III and only 7% older than age V. Fish caught in a 21-m wing trawl in spring 1981 also were of ages I to XII, but only 20% were older than III. They weighed up to 4.5 kg (9.9 pounds), and their average lengths at the ends of the first 3 years of life were 219, 345, and 444 mm.

Sherrell C. Jorgenson
LaRue Wells

Population Biology of Rainbow Smelt

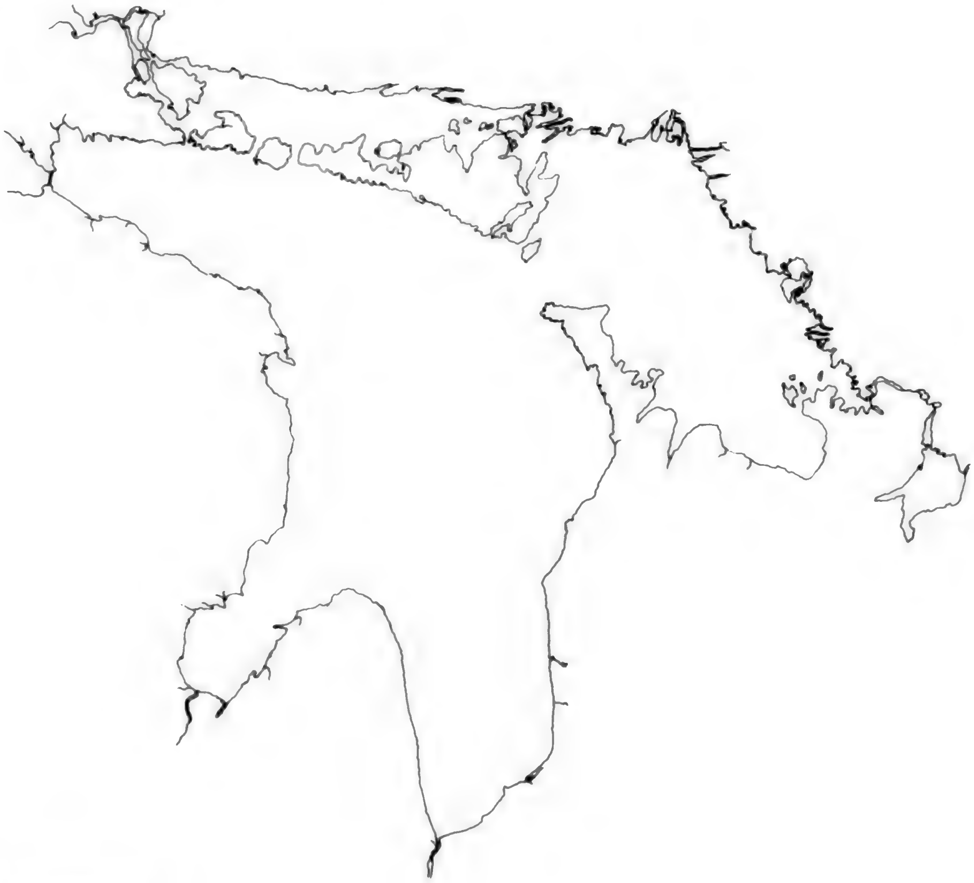
Catches of adult smelt in our fall 1981 survey increased nearly threefold from 1980 in the northwestern part of the lake, but changed little elsewhere. This species is nearly always more abundant in the northwestern part of the lake than in other areas, and this characteristic was particularly marked in 1981; the average catch at Manistique and Sturgeon Bay (combined) was nearly 10 times the combined average for the other six sampling stations. Catches of YOY smelt were generally down in all areas; the combined catch was little more than half that in 1980.

As judged by scale samples collected in 1980, smelt grow somewhat faster in southern Lake Michigan, where water temperatures are generally warmer, than in the northern part of the lake. For example, average lengths of females at the end of their second and third years of life were 134 and 174 mm in the southern part (data from Saugatuck, Benton Harbor, Waukegan, Port Washington, and Ludington combined) and 126 and 164 mm in the northern part (Sturgeon Bay, Manistique, and Frankfort).

Randall W. Owens
LaRue Wells

Lake Huron Fish Stocks

Ray L. Argyle, Project Leader



Status of Major Species

The success of programs aimed at rebuilding or establishing new populations of lake trout and other salmonids depends largely on the abundance and availability of suitable forage. Because alewives and smelt compose a sizable part of the forage, accurate determinations must be made of the size and age composition of these forage populations, their standing stocks and annual production, and the estimated potential demand on them by predators. Although our survey effort is directed mainly at alewives, smelt, and bloaters, information is also obtained on slimy and deepwater sculpins, and ninespine sticklebacks.

Alewives--The CPEs of adult alewives at all stations combined in our spring and fall 1981 surveys increased over those of 1980. The spring survey data, which are the best indicator of abundance, have shown a slow but steady increase in alewife abundance since 1979--a result of the recruitment of the strong 1976 and 1977 year classes into the catchable fraction of the stock. The 1976 year class has been unusual in not being well represented in the catches until ages IV and V (Table 3). The condition of adult alewives taken in the 1981 fall survey continues to be good. The age distribution was similar to that in past years (Table 3) and the average weight of adults captured was 36 g, or nearly 1.5 g heavier

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than the mean weight during 1972-81.

The standing stocks of adult alewives (based on stratified random sampling) available to the bottom trawls during the 1981 spring and fall surveys were estimated at 35,650 ± 1250 t (95% error bounds) and 11,800 ± 500 t, respectively. In comparison, standing stocks in 1980 were estimated at 27,700 ± 1800 t in spring and 5000 ± 300 t in fall. The standing stock estimates for 1981 are similar to the averages for the 9-year period 1973-81 of 31,500 t in spring and 13,000 t in fall.

The 1980 year class of alewives appeared to be extremely strong. The CPE for YOY was 718 and, although several unusually large trawl catches in 1981 tended to inflate the CPE, it was still substantially larger than the 1975 CPE of 207 which has proved to be a very strong year class. Also, young alewives in the 1981 year class were about average in weight (4.8 g) and should survive well over winter. The average weight of young alewives in the fall appears to be a big factor in their ability to successfully overwinter. For example, the CPE for young alewives in fall 1980 was 67 and, although the year class appeared to be very strong, the average weight was only 2.4 g. As a consequence, it was not well represented in spring 1981 catches, and analysis of age data from the fall 1981 surveys indicated that the 1980 year class was only of about average strength (Table 3).

Table 3. Age distribution (percentage) of Lake Huron alewives of the 1967-80 year classes that were available to bottom trawls, November 1973-81. The percentage age distributions were based on yearly collections of 450 to 600 scales, and the ages determined from these were expanded by applying the length-frequency distributions for each respective year.

Year of capture	Age group I	II	III	IV	V	VI	VII
1973	13	13	35	28	10	2	
1974	26	11	28	23	9	2	<1
1975	13	25	25	24	11	2	<1
1976	15	12	28	26	14	4	1
1977	6	44	31	16	3	<1	
1978	37	12	37	12	2		<1
1979	28	15	13	25	15	3	<1
1980	28	11	18	23	17	2	1
1981[a]	21	12	17	27	18	4	1

[a] Age provisional; obtained from length-frequency distribution.

Smelt--The CPE of adult rainbow smelt was smaller in spring 1981 than in spring 1980, but the CPE in fall 1981 (780) was nearly double that in fall 1980. Because the spring surveys coincide with the spawning run, and anomalies in timing may influence the availability of adult smelt to our trawls, the fall survey data are the best indicators of abundance. The large increase in the adult smelt population reflected in the fall surveys is due to recruitment of a series of strong year classes produced in 1978, 1979, and 1980.

The adult population continues to be composed predominantly of fish of ages I, II, and III (Table 4). However, there is some evidence of a decline in growth of fish in these size groups (examination of the age and growth data is incomplete). The size of the standing stock of smelt available to bottom trawls in fall 1981 was estimated at 36,500 ± 4800 t compared with 27,000 ± 1800 t in fall 1980.

The 1981 year class appears to be strong, but not as strong as the 1980 year class. The average size (length and weight) of YOY smelt captured in fall 1981 was about the same as in past years, and we expect that smelt abundance will remain high.

Table 4. Age distribution (percentage) of Lake Huron smelt available to bottom trawls and representing the 1969 to 1980 year classes, November 1975-81. The percentage age distributions were based on yearly collections of 450 to 600 scales, and the ages determined from these were expanded by the length-frequency distributions for each respective year.

Year of capture	Age group					
	I	II	III	IV	V	VI
1975	30	53	14	2	<1	<1
1976	30	54	12	1	2	<1
1977	35	46	15	3	<1	<1
1978	46	39	11	3	<1	<1
1979	64	29	6	1	<1	0
1980	46	46	7	1	<1	0
1981[a]	56	30	10	2	>1	>1

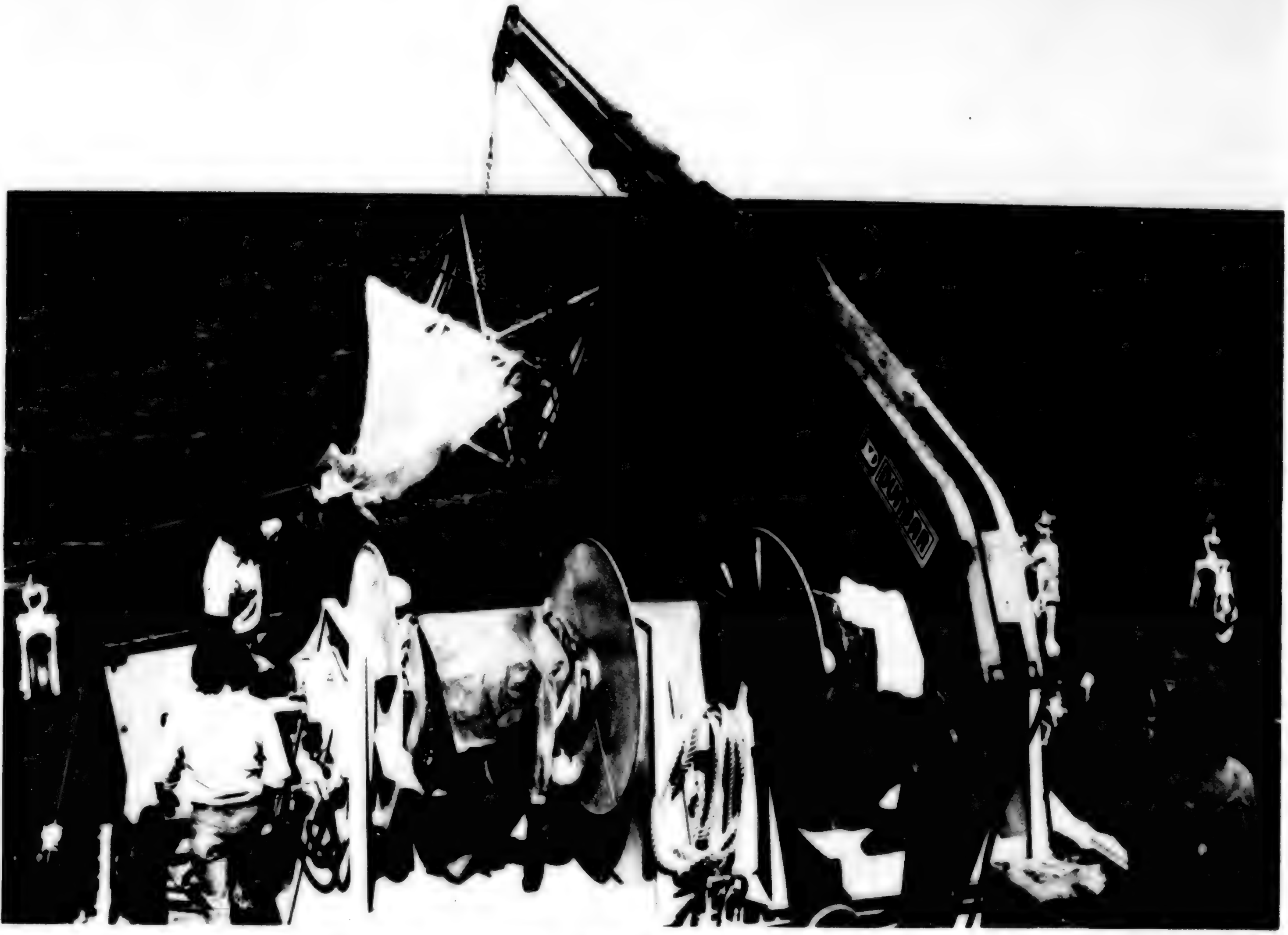
[a] Age provisional; estimated from length-frequency distribution.

Other species--The CPE for slimy sculpins in fall 1981 was nearly identical to that of 1980, whereas catches of ninespine sticklebacks declined slightly. The abundance of deepwater sculpins was unchanged from that of previous years. One shortnose cisco (*Coregonus reighardi*) was caught--the first one collected since 1977.

Biomass and production of alewives--The catch data from our systematic surveys are routinely used to estimate the biomass of the major forage stocks (mainly alewives, smelt, and sculpins) available to the trawling gear. However, analysis of data from supplementary surveys with larger trawls and surveys in midwater shows that the true size of the standing stock is often considerably larger than the estimates indicate, because fish of the younger age groups (particularly alewives) are not fully vulnerable to the trawling gear. To adjust for this problem of vulnerability, we constructed hypothetical alewife populations from survey data collected during spring and fall 1973-80, based on seasonal survival curves and the assumption that alewives become fully vulnerable to the trawl at age V during spring. Biomass estimates of the hypothetical populations ranged from about 80,000 to nearly 210,000 t during the 8-year period, and the estimates were consistently larger in fall than in spring. These estimates averaged 4.5 (SE = 0.65) times larger than the previous estimates (unadjusted for members of younger age groups present but not captured) calculated from the spring survey data, and 12.5 (SE = 1.4) times larger than the previous estimates from the fall data.

Estimates of production were also based on the hypothetical populations. Total annual production of alewives in U.S. waters of Lake Huron was calculated by applying previously derived estimates for growth and mortality to the hypothetical populations. Production estimates for the 8-year period ranged from 450,000 to nearly 1.3 million t; with over 90% of the production occurred during the first 2 years of life.

Ray L. Argyle
Susan E. Baker
Ralph M. Stedman



Researchers aboard the R/V Grayling on Lake Huron collect samples with a plankton net.

Rate of Forage Fish Use by Major Predators

The availability of suitable forage is basic to the success of the intensive program to rehabilitate populations of lake trout and to sustain populations of other salmonids in Lake Huron.

During 1981, we collected stomachs from 499 lake trout through the spring, summer, and fall during our own surveys and in cooperation with biologists of the Michigan Department of the Natural Resources. Analysis of the stomach contents showed that smelt are the most frequently eaten item in the lake trout diet, followed by alewives and sculpins (Table 5). Of the fish that could be identified in the stomachs, smelt made up 57%, whereas alewives and slimy and deepwater sculpins (combined) made up 31% and 12%, respectively. Whether the predominance of smelt in the diet indicates a food preference or is simply related to availability is not known.

The percent frequencies of occurrence of smelt and alewives in the diet of lake trout were similar to those in 1980. However, the average size of smelt eaten by lake trout this year was smaller and the average number consumed per lake trout was larger; these changes in the size and number of smelt eaten corresponded with changes in the smelt population--namely an increase in number and a decrease in mean size.

Susan E. Baker
Ray L. Argyle

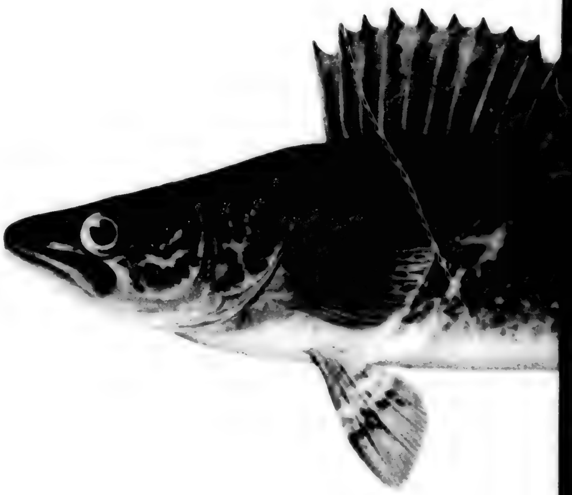


Table 5. Percent frequency of occurrence of diet items found in lake trout of different length classes captured in 1981 in Lake Huron, all seasons combined.

Total length (mm)	Number of fish examined	Number of stomachs containing food	Food				
			Invertebrates	Smelt	Alewives	Sculpins	Unidentified fish remains
100-199	15	11	55	9	9	0	36
200-299	36	29	7	14	17	17	94
300-399	80	63	0	25	11	49	35
400-499	84	70	0	46	20	23	36
500-599	107	85	0	60	28	11	40
600-699	115	97	0	53	51	1	35
700-799	61	55	0	47	69	4	22
800-899	1	1	0	0	100	0	0

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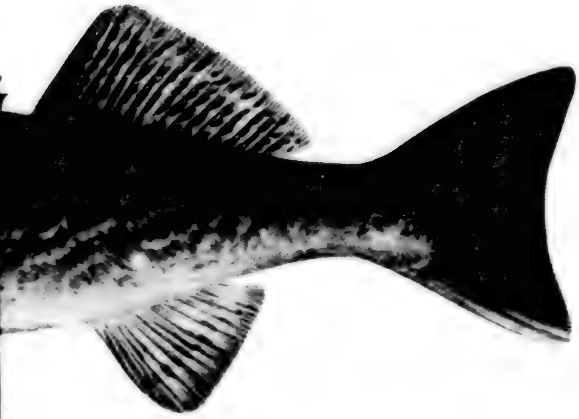
Structure, Movement, and Integrity of Walleye Stocks in Southern Lake Michigan

As part of an interagency study to determine the biological character, temporal distribution, and spatial relations of components of the walleye resource in the southern Lake Huron, Lake St. Clair, and western Lake Erie complex, we continued to coordinate through correspondence and workshops the various state and provincial agencies involved in the comprehensive tag and recapture program. Tagging studies by the Michigan Department of Natural Resources and the Ontario Ministry of Natural Resources in Lakes St. Clair and Erie (near Monroe) and the Service (Division of Ecological Services) in the Clinton River (a tributary to Lake St. Clair) were continued in 1981. About 10,000 walleyes were tagged in 1981, and the tag returns by the end of 1981 were about 6%--very similar to the rate in 1980. Preliminary examination of the recapture data indicates that walleyes tagged in the northeastern portion of the western basin of Lake Erie tended to remain in the basin; some of the walleyes tagged in the northwestern portion of the western basin were recaptured in Lake St. Clair, and walleyes tagged in Lake St. Clair; and its tributaries traveled extensively throughout Lake St. Clair, and substantial numbers was also recaptured in the St. Clair River and in southern Lake Huron.



Walleye

Ray L. Argyle
Wilbur L. Hartman

Performance and Status of Bloater Stocks

Bloater stocks showed a steady improvement in Lake Huron in 1981. Catches of bloaters in gillnet and trawl surveys increased substantially from those of 1980. The CPE for bloaters in gillnets (one unit of effort equals 2200 feet of graded-mesh gillnet set overnight) increased from 33 in 1980 to 57 in 1981. The CPE of adults in the fall 1981 trawl survey was 10.6 compared with 4.8 in fall 1980, and the standing stock of adult bloaters available to bottom trawls was estimated at 3200 ± 700 t in fall 1981 versus 1300 ± 500 t in fall 1980.

Catches of YOY bloaters in fall 1981 indicate that a strong year class was produced in 1981. Relatively good year classes have been produced each year in 1977-81, and as these year classes recruit into the spawning stock the bloater population should continue to rebuild.

Ray L. Argyle
Ralph M. Stedman
Susan E. Baker

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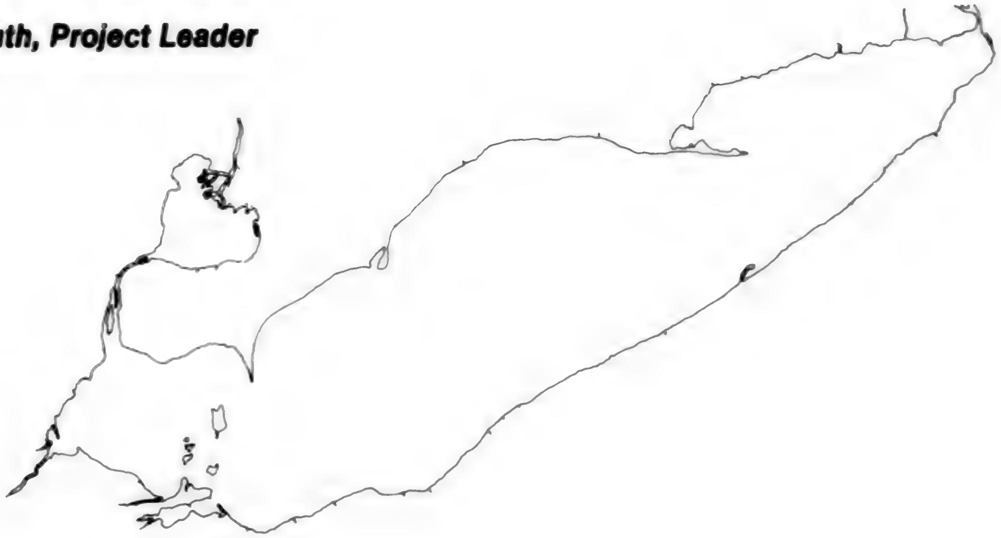
Lake Erie Fish Stocks

Kenneth M. Muth, Project Leader



Status of Major Species

Walleyes--Spring sampling of walleyes from commercial fishery catches was restricted to the western basin. The New York Department of Environmental Conservation (NYDEC) was unable to obtain eastern basin samples due to adverse weather conditions that limited commercial fishery catches and thus sampling activities. Walleye samples from western basin trapnets consisted of 498 fish and included eight year classes. The strong 1977 year class and a good 1979 year class composed 37 and 24% of the sample, respectively. Relatively good numbers of older fish (ages V, VI, and VII) were present. Although all females age IV and older were mature, only 92% of those of age III and none of age II were mature.

A total of 337 walleyes were sampled from western basin trapnets during the fall. Yearling fish (1980 year class) dominated the age groups sampled (52%), and relatively good numbers of fish of the 1979 and 1978 year classes were present, constituting 23 and 14% of the sample, respectively. We completed an age analysis based on scales and length data for 471 walleyes from eastern basin gillnet catches that were provided by NYDEC. Nine age groups (ages II to X inclusive) were represented; the 1978 and 1977 year classes constituted 49 and 24% of the sample, respectively. Only 4.3% of the females of age II were mature, 85.6% of age III, and nearly 100% of age IV.

A persistent concern for potential decline in growth rate of western basin walleyes has been expressed by various management agencies because the stock has increased dramatically as a result of interagency management under the walleye quota system. The hypothesis of declining walleye growth was tested by comparing FWS walleye weight at length and length at age data obtained in 1964, 1965, 1968, and 1969 with recent growth data obtained in 1976-80. Results of this analysis indicate that walleye growth during the past 5 years has been generally equal to, or perhaps even better than during the presumably better growth years of the 1960's when the abundance of walleyes was low.

Yellow perch--Age determinations were made for 2,260 yellow perch sampled from net-run trapnet and landed gillnet catches in the western, central, and eastern basins during spring and fall 1981. Year class strength varied noticeably between basins and seasons. In spring, western basin trapnet catches were composed mainly of two year classes, the relatively strong 1977 year class (59%) and the 1976 year class (26%). Few fish of the 1978 year class were taken. By fall, however, the 1976 year class had passed through the fishery and representation by the 1978 and 1977 year classes was almost identical (40% and 39% respectively). The relatively strong 1979 year class entered the fishery in the fall in substantial numbers as earlier predicted.

In the central basin, spring catches were also dominated by the 1977 year class (57%) followed by the 1978 year class (35%). The fall catches were strongly represented by the 1979 year class (63%) followed by the 1978 year class (26%). Representation of the 1977 year class dropped to 10%. Eastern basin spring catches were composed of mainly two year classes, 1978 and 1977, constituting 48 and 41% of the samples, respectively. By fall, representation by the 1978 year class remained at 48% but that of the 1977 year class dropped to 18%. As in the western basin, the 1979 year class entered the fishery in fairly large numbers (29%).

Length-frequency distributions of yellow perch were constructed from 1981 samples from each basin to determine the percentage of the catch that was less than 8 inches long, the current commercial minimum legal size limit in Ohio and Ontario. In net-run catches, nearly 12% of the fish were shorter than 8 inches in the spring and 24% in the fall in trapnet catches in the western basin; 1% in the spring and 4% in the fall in gillnet catches in the central basin, and 7% in the spring and 4% in the fall in the eastern basin gillnet fishery.

A yellow perch technical committee was established by the Lake Erie Committee of the Great Lakes Fishery Commission to develop the technical basis for interagency (quota) management of the depressed yellow perch stocks in the central basin. The considerable data we have gathered over the years were pooled with those from the state and provincial agencies involved, and we participated in the development of a preliminary technical system for quota management, which was submitted to the agencies for review.

Kenneth M. Muth
David R. Wolfert
Michael T. Bur

Appraisal of Lake Trout Restoration Efforts

Budgetary limitations restricted our lake trout sampling program in the eastern basin of Lake Erie to a single fall survey. Adverse weather conditions and equipment malfunctions further limited data collection to bottom trawl sampling. Only three juvenile lake trout were collected at the 80- and 140-foot depths offshore from Dunkirk and Barcelona, New York. An adipose finclip was observed on two of the three fish and one specimen had a coded wire tag which identified it as being stocked as a yearling in 1981. Digestive tract analysis revealed that amphipods and chironomids were the most numerous food items consumed by these lake trout, but YOY smelt constituted the greatest volume consumed.

Michael T. Bur

Distribution, Composition, and Standing Stocks of Forage Fish

Six surveys at the Bono and East Harbor stations in the western basin of Lake Erie were conducted in 1981 to obtain samples of emerald and spottail shiners, trout-perch, alewives, and gizzard shad for the study of forage fish abundance, distribution, and population dynamics. Field work has now been completed for this 3-year study and data analyses are in progress.

Catches of forage fish in 1981 were noticeably lower than catches from the same time periods in 1979 and 1980. Reasons for this apparent decrease in forage abundance are not known. Forage fish distribution patterns at our two sampling stations may have been altered in spring 1981 by the very slow water warming rate and the large number of storms that contributed to high turbidity in nearshore waters. Alternately, forage fish abundance may have been suppressed by predation from the very abundant walleyes.

Samples of predator fish stomachs were collected in conjunction with the forage fish studies to determine predator-prey relations in the western basin fish community. Two predator food-habit studies in cooperation with the Ohio State Cooperative Fishery Research Unit were initiated in 1981. One graduate student is analyzing the use of forage fishes by walleyes and yellow perch in western Lake Erie and these results will be supplemented by additional studies of yellow perch and white bass feeding behavior conducted by FWS personnel. A second graduate student is studying the population ecology of the white perch in Lake Erie.

Preliminary results from the predator food-habit studies indicate that all four species of predators eat some or all of the forage fish species being studied. Prey use varies with the size of the predator, the size and availability of the prey, the time of day, and the season.

Samples of YOY walleyes obtained during July through November 1981 indicated that YOY emerald shiners were a preferred forage species but YOY white bass, gizzard shad, rainbow smelt, spottail shiners, alewives, and white perch were also readily eaten. Relatively few invertebrates (copepods and chironomid larvae) were consumed by YOY walleyes. Yearling walleyes tended to be crepuscular feeders during April and May, but foraging apparently shifted to morning and afternoon periods after June. Both forage fish and invertebrates (chironomids) were eaten in April and May, but yearling walleyes became more piscivorous after June, as newly hatched YOY of various species became more readily available. Adult walleyes consumed a surprisingly high number of invertebrates (primarily cladocerans) during June and July, but were still strongly piscivorous throughout the year. Generally, emerald shiners were the preferred forage species for both yearling and adult walleyes but other forage species were used extensively, the seasonally most abundant forage species being the

most frequently consumed.

Yellow perch of all sizes depended largely on invertebrate prey as a food resource. Chironomids, fingernail clams, copepods, amphipods, and water mites were the items most frequently eaten. However, larger perch (150 mm long or longer) used forage fish extensively after July when the YOY of various species become available. Shiners were the preferred forage, but gizzard shad, alewives, and freshwater drum were also consumed.

White bass were predominantly piscivorous feeders, eating YOY gizzard shad, emerald shiners, white bass, and freshwater drum.

Most of the white perch stomachs available for feeding analysis came from smaller fish (primarily yearlings) because this exotic species has only recently become established in western Lake Erie, and large numbers of older, larger white perch have not been available. Cladocerans and chironomids were the primary prey of small white perch, but stomachs from a few larger white perch obtained in the fall also contained YOY gizzard shad and shiners. Competition between white perch and native predator species for forage fish resources may have a negative impact on native fish populations as the white perch population continues to expand rapidly.

Kenneth M. Muth

Biology, Performance, and Yield of Rainbow Smelt

A study of rainbow smelt populations in U.S. waters of the central and eastern basin in Lake Erie was initiated in 1978 and field work was concluded in 1980. Objectives of the study were to describe the population dynamics and distribution patterns, and to estimate the biomass of smelt so that this information would be available for developing future harvest management strategies if this species becomes a target of U.S. commercial fisheries.

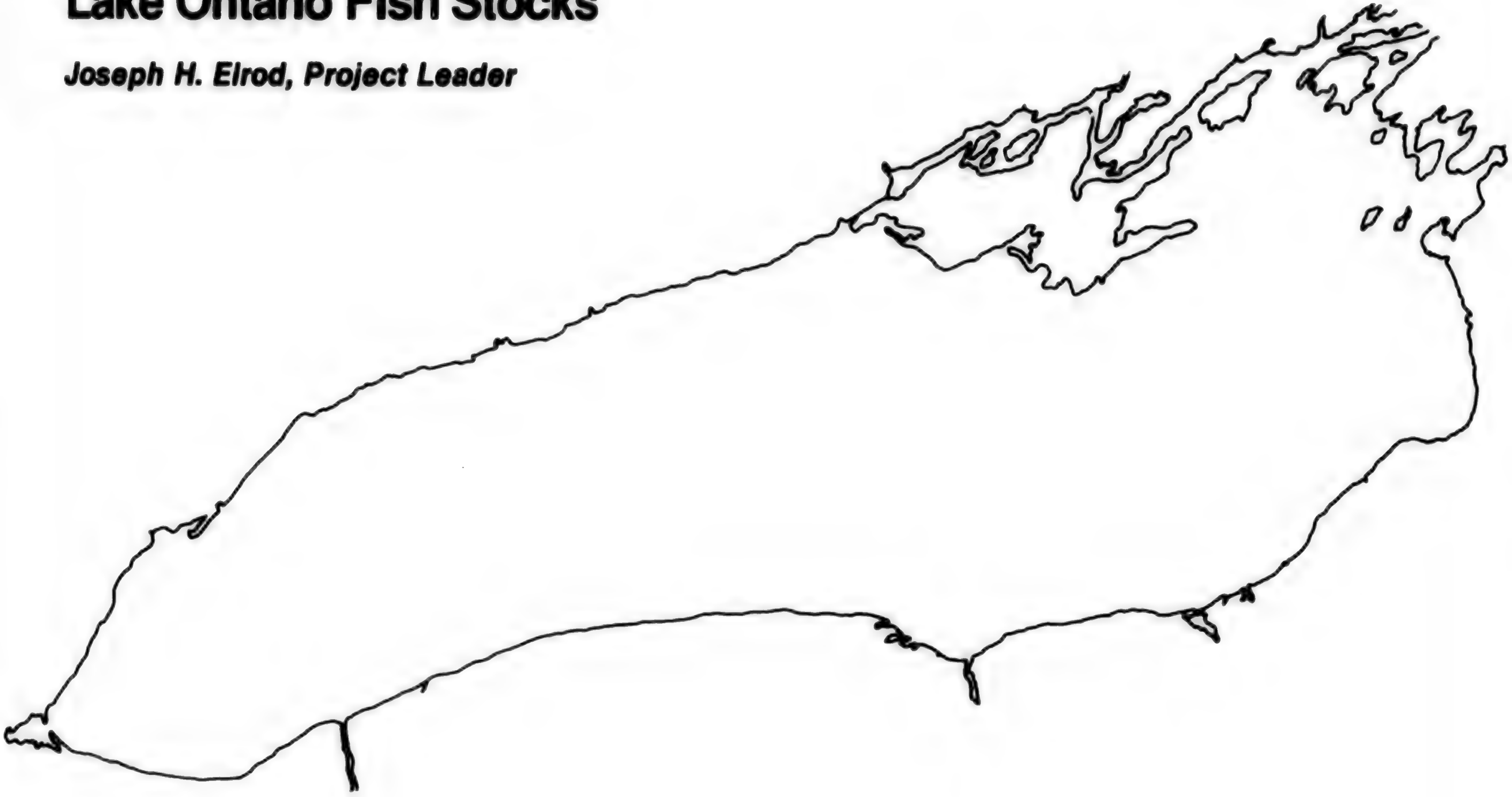
Analysis of smelt scale samples indicated that the population is composed of relatively few age groups. Age composition varied from year to year, but yearling and 2-year-old fish constituted from 80 to 98% of the pre-spawning samples. Age III fish composed 3.5% or less of the samples, and fish of ages IV and V contributed less than 1% to the samples.

Estimates of smelt biomass derived from bottom trawling data are conservative, and have wide confidence intervals because fish that are not occupying the bottom stratum are not sampled. However, echo tracings made during trawl tows in spring and fall 1978 indicated that most smelt were in the bottom 5-ft stratum; consequently biomass estimates from these samples seem to be the most reliable. The biomass estimate of marketable smelt during the spring of 1978 in central basin waters was over 47 million pounds. Since marketable smelt are defined as fish longer than 65 mm, yearling fish are not included in the potential spring harvest. Massive post-spawning mortality was observed in spring 1978, and that large loss of older fish was only partly offset by recruitment of yearling fish into the potential 1978 fall fishery, so the 1978 harvestable biomass drastically declined to only 18 million pounds. Biomass estimates derived from other sampling periods in 1979 and 1980 ranged between about 7 and 24 million pounds, but sampling errors induced by smelt distribution patterns within the water column make these biomass estimates suspect.

David R. Wolfert

Lake Ontario Fish Stocks

Joseph H. Elrod, Project Leader



Status of Major Species

An adequate forage base is essential for success of programs by U.S. and Canadian fishery agencies to reestablish self-sustaining lake trout populations and to sustain populations of other trout (brown and rainbow) and salmon (coho and chinook). Current knowledge of the status of the forage fish stocks (principally alewives, rainbow smelt, and slimy sculpins) is needed to formulate management decisions designed to perpetuate vigorous stocks of both predator and prey species.

During 1978, in cooperation with the New York Department of Environmental Conservation, we began a program to assess forage fish stocks. For the last 4 years, we have conducted systematic bottom trawling in spring for alewives, in summer for rainbow smelt, and in fall for slimy sculpins.

Alewives--Changes in abundance indices, individual growth rates, and individual weights all indicate that numbers of alewives have increased steadily since the catastrophic die-off during the winter of 1976-77. The index of abundance for adults (age II and older) during spring 1981 was nearly 3 times that of the previous year (Fig. 1). For yearlings, the 1981 index was 672--much higher than the indices for 1980 (271), 1979 (43), and 1978 (185). Although the abundance of alewives has clearly increased, the 1981 indices undoubtedly overestimate the magnitude of that increase. Acoustical records show that alewives were more closely associated with the bottom and thus more available to our bottom trawl during spring in 1981 than in previous years.

Fast growth during 1977 formed

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an unmistakable, wide growth band on the scales that enabled us to accurately age older adult alewives, even though annual mark(s) have not formed on some scales during the past 3 years. Examination of scales from 193 alewives of the 1971-75 year classes from 1981 catches revealed that 51% were missing 1 annulus, 44% were missing 2 annuli, and 1% were missing 3 annuli. We cannot determine for certain in which year or years these fish failed to grow. However, the increasing frequency of missing marks in the spring of recent years (0 in 1978-79, 54% in 1980, and 96% in 1981) suggests that fish missing three annuli (1%) did not grow in 1978; fish missing two or three annuli (45%) did not grow in 1979; and fish missing one, two, or three annuli (96%) did not grow in 1980. A gradual cessation of growth among older individuals as the population increased agrees with our observation that during the population buildup, length increments gained by fish in their second and third years of life decreased each year. There is no way to determine whether alewives in year classes produced since the 1976-77 die-off have also stopped growing because their scales lack the distinctively wide 1977 "growth band." But we strongly suspect that the largest members of the 1977 year class (age IV in 1981) failed to grow during 1980. Thus we have, to an unknown but probably small extent, underestimated fish of age IV and overestimated those of age III in the survey catches.

The condition of alewives, weight at length, has generally been related to their capacity to survive the stress of winter. The condition of alewives has declined steadily since fall 1977, and in fall 1980 it was poor and identical with that before the massive winter die-off of 1976-77. Consequently, we expected that considerable mortality might occur during the winter of 1980-81. Few dead alewives were collected, however, during the spring 1981 survey. The winter of 1980-81 was not as harsh as that of 1976-77, suggesting that climatic factors can be as important as condition in determining the magnitude of winter die-offs.

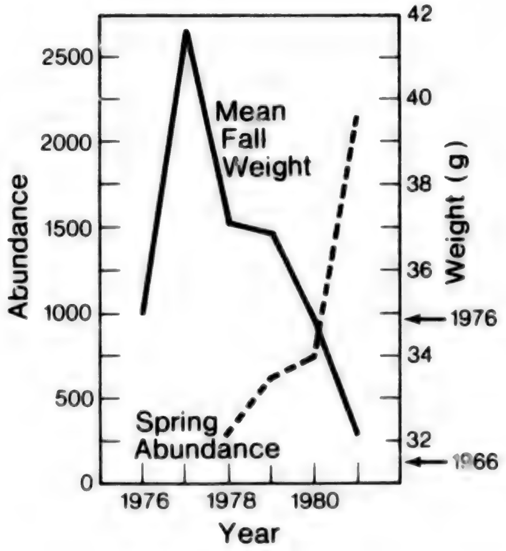


Fig. 1. Adult alewives, abundance in the spring (dashed line), and mean weight in the fall (solid line). Arrows denote mean weights of adult alewives in Lakes Michigan and Ontario during the fall of 1966 and 1976, respectively, prior to massive die-offs.

> ***"Clearly, the condition of the alewife stock in Lake Ontario is now so poor that a small adverse change in environmental conditions could precipitate another mass mortality."***

In 1981, with no significant die-offs to reduce alewife numbers and with a large 1980 year class adding to the population, the population must have increased greatly. This presumed increase was accompanied by another rather large decline in condition. In fall 1981, mean weight of mature alewives in Lake Ontario was similar to that of alewives in Lake Michigan in 1966, before a large die-off. Clearly, the condition of the alewife stock in Lake Ontario is now so poor that a small adverse change in environmental conditions could precipitate another mass mortality.

Rainbow Smelt--The 1981 indices of abundance for yearling and adult smelt were 65% lower and 34% higher, respectively, than in 1980. Changes in the indices of biomass were similar. The index of abundance for adult smelt in 1981 was the highest since we began trawling in 1978. Abundance of yearlings has tended to fluctuate much more widely, with alternating weak and strong year classes. Year classes produced in odd-numbered years have been 3 to 5 times more abundant than year classes produced in even-numbered years.

To understand predator-prey interactions in Lake Ontario, it is essential to describe the seasonal distribution pattern of smelt. The late fall distribution first examined in 1981 was substantially different from what we had previously hypothesized on the basis of observations in early fall. Bottom and mid-water trawling conducted from early summer through early fall in 1978 and 1980 showed that smelt were close to bottom during the day, and that 95% or more of the population were shoreward of the 60-m depth contour. However, midwater trawling and acoustic surveys at night demonstrated that smelt moved off bottom after dark to a zone just below the thermocline, but then returned to near bottom by daylight. We believed that this general pattern also held true through the late fall and winter. However, echograms made during October 1981 showed what appeared to be most of the alewives and smelt off bottom and at midwater depths of 40 to 70 m during the day. Catches with a 14-m midwater trawl subsequently confirmed this observation and further showed that the midwater smelt distribution extended at least as far as 18 km offshore over a depth of 220 m. We observed no change in the distribution during acoustical surveys made over the same area in mid-November and mid-December.

Slimy Sculpin--Catches of slimy sculpins were similar to those made at the same transects in 1980. Indices of abundance and biomass were 2 and 8% lower, respectively. Sculpins made up 42% by weight of the fish in 3,554 stomachs of young lake trout 100-450 mm long collected between April and October in 1978-81. Despite the preference of young lake trout for sculpins, there has been no apparent depression of the sculpin stock after 4 years of intensive lake trout stocking.

Robert O'Gorman
Roger A. Bergstedt

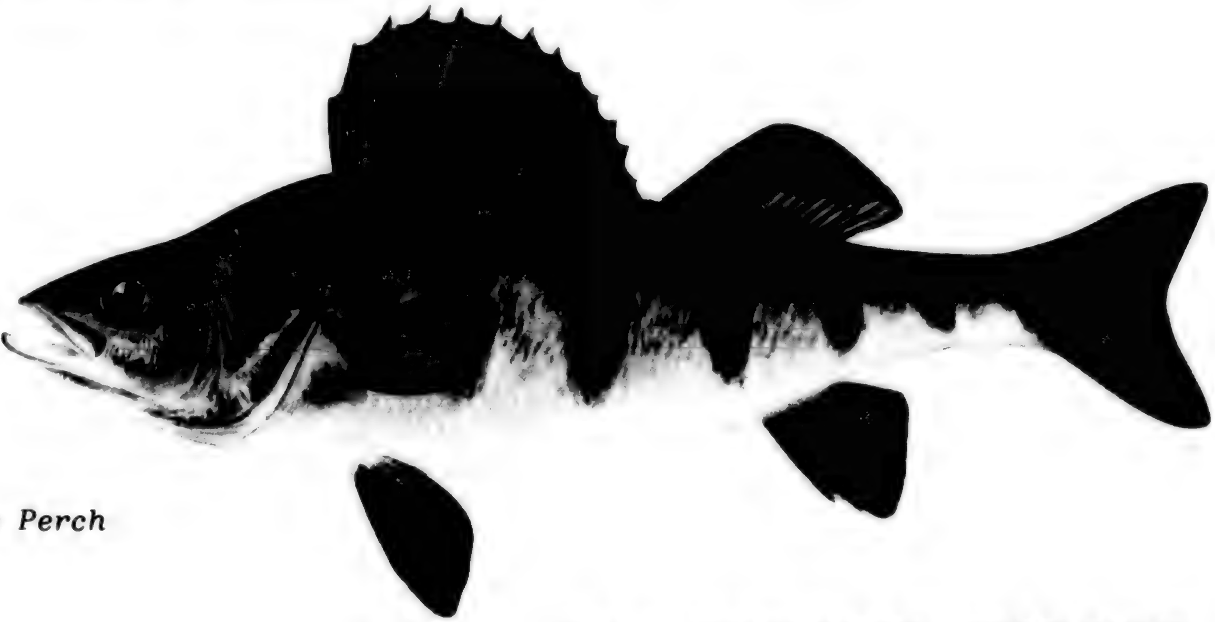
Assessment of Juvenile Fishes in Nearshore Waters

Reproductive success of white perch, yellow perch, spottail shiners, and trout-perch has been determined each fall since 1978 from the numbers of YOY caught with a 26-foot (headrope length) bottom trawl. The annual survey also provides information on abundance of adult (age-I and older) yellow perch, spottail shiners, and trout-perch.

In the bays of northeastern Lake Ontario, reproductive success in 1981 was extremely poor for yellow perch and white perch, poor for spottail shiners, and average for trout-perch. Not a single YOY yellow perch was captured in 1-1/4 hours of trawling and the 122 YOY white perch captured were but a small fraction of any past year's catch. Yellow perch have produced only one strong year class (1978) since 1977 and these fish, now age III, made up about 75% of the survey catch. Annual mortality for the 1978 year class increased from 0.33 during 1978-80 to 0.60 during 1980-81, presumably because the fish attained a size vulnerable to the fishery. Due to increased exploitation of the dominant year class and little recruitment to the adult stock, the 1981 catch of adult yellow perch in our surveys declined 58% from the previous year and was similar to that of 1978. By the fall of 1982, with poor recruitment and annual mortality of the 1978 cohort expected to increase to 0.70, the abundance of adults will fall to the lowest level we have yet observed.

In southeastern Lake Ontario, where sampling began in 1979, yearly differences in depth of the thermocline, and thus in area above the thermocline inhabitated by target species, reduced the accuracy of abundance estimates for this region. After adjusting for the area of warm-water habitat available each year, the data indicated that abundance of both YOY and adult trout-perch and spottail shiners was higher in 1981 than in the previous 2 years. White perch produced a year class weaker than that in 1979 and about the same size as that of 1980. Reproduction of yellow perch was extremely poor in this region of the lake also; only one YOY was caught in 1-1/3 hours of trawling. However, unlike the situation in the northeastern bays, adult yellow perch were more abundant than in 1980 but somewhat less abundant than in 1979.

Robert O'Gorman



Yellow Perch

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Appraisal of Lake Trout Restoration and Sea Lamprey Control

The experimental design implemented in fall 1979 for marking lake trout stocked in U.S. waters allows us to (1) determine relative survival and movement of fish stocked at six locations; (2) compare performance of fish stocked during fall and spring; and (3) compare performance of three strains of lake trout (Lake Superior [SUP]; Clearwater Lake, Manitoba [CWL]; and Seneca Lake, New York [SEN]). The various groups of fish are identified by an adipose finclip (Ad) and a uniquely coded-wire tag (CWT) injected into the snout.

An interagency bottom trawling survey in which FWS, New York Department of Environmental Conservation, and the Ontario Ministry of Natural Resources participated was conducted during mid-summer 1981 for the third consecutive year to gather data for assessing the performance of various cohorts of juvenile lake trout. New York's R/V Seth Green made 53 trawl hauls in 6 areas and the Service's R/V Kaho made 90 trawl hauls in 11 areas (24 hauls in 4 areas in Canadian waters of western Lake Ontario, with Ontario biologists on board). Yearlings and 2-year-olds each made up 47% of the 2,014 lake trout captured. A coded wire tag was recovered from each of 859 fish.

Data from midsummer trawl surveys indicated that CWL fish grew faster than SUP fish. Mean lengths of lake trout collected with gillnets during September were consistent with this observation, and also showed that growth of CWL fish was faster than that of SEN fish. However, relatively few CWL fish have survived past age III. Data from fish marked with CWTs suggest that poor survival of CWL fish begins immediately after stocking. Fingerlings were stocked in the ratio of 1 CWL : 1.5 SUP in October 1979; by September 1981, however, 55 SUP fish from this release had been recovered with bottom trawls, but no CWL fish had been recovered. CWL and SUP yearlings marked AdCWT, and SUP yearlings marked with an AdLP clip, were stocked in spring 1981. Three months later, catches of CWL fish in proportion to the numbers stocked were significantly lower ($P < 0.001$) than either group of SUP fish. If this poor performance is supported by additional evidence, fishery managers must begin questioning the suitability of CWL strain lake trout for further introduction into Lake Ontario as a potential brood stock for restoration of self-renewing populations.

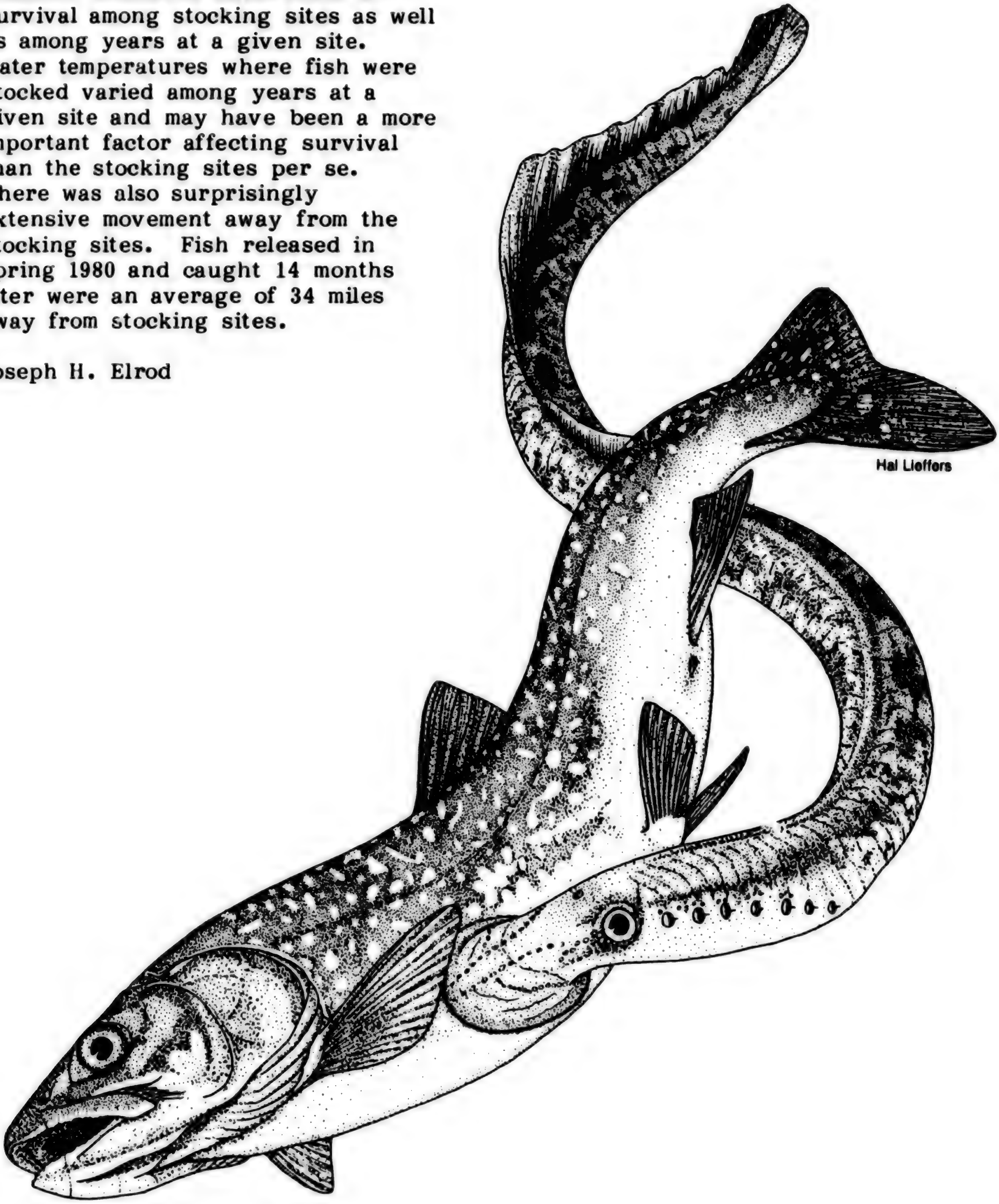
Mean total length (mm) of each age group in September

	Age Groups			
Strain	II	III	IV	V
SUP	349	476	550	-
SEN	-	507	-	-
CWL	432	530	601	651

Because SEN fish were in short supply, yearlings were stocked at only two locations in spring 1981, along with nearly identical numbers of CWL and SUP fish. Catches near those stocking sites in mid-summer 1981 were lower for SEN fish (13) than for CWL (31) or SUP fish (56) and were significantly different ($P < 0.001$) from the ratios stocked. As SEN fish will continue to be in short supply for at least 2 more years, a definitive evaluation of their performance will be delayed for some time.

Catches of lake trout from identical groups stocked at six locations indicated differences in survival among stocking sites as well as among years at a given site. Water temperatures where fish were stocked varied among years at a given site and may have been a more important factor affecting survival than the stocking sites per se. There was also surprisingly extensive movement away from the stocking sites. Fish released in spring 1980 and caught 14 months later were an average of 34 miles away from stocking sites.

Joseph H. Elrod



Population Dynamics

Edward H. Brown, Jr., Project Leader

Size, Productivity, and Harvestable Surplus of Great Lakes Fish Stocks

In response to charges given to the Tripartite Technical Working Group on assessment of major fish stocks in treaty-ceded waters of the State of Michigan, we assessed the status of the following species: lake trout in Lakes Superior, Michigan, and Huron; smelt in Lakes Michigan and Huron; and bloaters in Lake Michigan. We also assisted Michigan and tribal biologists in completing assessments of other stocks, including those of lake whitefish, lake herring, and chubs, in one or more of the lakes. Our findings, including total allowable catches for the various species when biologically warranted, were incorporated as separate sections of a report submitted to representatives of the Department of the Interior, the State of Michigan, and the Upper Michigan communities of Chippewa and Ottawa Indians.

Comparison of 1980 landings from ceded waters with recommended 1981 total allowable catches (Table 6) indicated that these catches are now being exceeded for both lake trout and lake whitefish by the competing fisheries in some areas. In contrast, the recovering bloater population in Lake Michigan and the stable chub resource in Lake Superior are perhaps slightly to moderately underused. However, because of the severely depleted state of the Lake Michigan stocks during the mid-1970s, some resource managers conclude that further protection is needed so that chubs can fully attain their productive potential in the ceded area.

Using area-depth stratifications developed earlier from 1973-78 data, we estimated (Table 7) the biomasses of forage fish available in fall 1980 to bottom trawls and presumably to salmonid predators in Lake Michigan. The lakewide biomass of adult alewives, a species that has dominated the forage base since long before the lakewide survey was begun in 1973, declined in 1980 to the comparatively low level of 1976-1977. In contrast, the biomass of adult smelt increased to the highest recorded since 1974, and biomass for all life stages of slimy sculpins combined (YOY are not distinguished in the surveys) remained, as in 1979, slightly below the 1973-80 average (1,300 metric tons) for that species. Availability to predators of YOY alewives and smelt was high in 1980: Estimated biomasses of alewives were second highest and those of smelt were highest for the period 1973-80.

Richard W. Hatch
Edward H. Brown, Jr.

Table 6. Landings (thousands of pounds) in 1980 and recommended total allowable catches (TAC) for 1981 of the three species of greatest importance to all user groups in the treaty-ceded waters of the State of Michigan.

Species	Lake Michigan	Lake Huron	Lake Superior
Lake trout			
1980 catch	582	22	76
1981 TAC	473	180	117
Lake whitefish			
1980 catch	2,978	677	654
1981 TAC	2,943	670	422
Chubs			
1980 catch	239	0	177
1981 TAC	1,000	0	342

Table 7. Estimates of biomasses of forage fish available in fall 1980.

Species and Life Stage	Point Estimate (thousands of metric tons)	Confidence Interval (90%)
Alewife		
Adult	47.5	31.9-63.2
YOY	17.2	7.4-27.1
Total	64.7	39.3-90.3
Smelt		
Adult	16.7	12.6-21.0
YOY	2.5	1.8-3.2
Total	19.2	14.4-24.2
Slimy Sculpin		
Adult and YOY	1.0	0.5-1.5
Combined total	84.9	54-116

Differentiation of Endemic Stocks and Introduced Strains of Lake Trout in the Great Lakes

Our electrophoretic survey of allelic variation in lake trout of three hatchery strains (Marquette, Manitoba, and Seneca Lake) was completed this year. Of a total of 67 loci representing at 28 enzymes, only 5 loci exhibited polymorphisms. Allelic variants were found at glucose-phosphate isomerase (GPI-1), malate dehydrogenase (MDH-2 and MDH-4), phosphoglucomutase (PGM-2), and superoxide dismutase (SOD-2). Clearwater Lake, Manitoba, trout (made available by the Service's Allegheny National Fish Hatchery) had the greatest amount of genetic variability at these loci. Mean heterozygosity (over all loci) was 0.013, a value only slightly lower than the 0.014 found by another investigator for wild trout in Lake Superior. Lake trout of the Marquette "lean" strain (made available by the Service's Jordan River National Fish Hatchery) with a mean heterozygosity of 0.003 were considerably less variable genetically than representatives of their parent populations in Lake Superior (H = 0.014). Evidently, some genetic variability in the wild stock has been lost during hatchery-culturing of this strain. Unfortunately, no allelic data with which to compare our findings of no variability in the Seneca Lake hatchery strain (from the Service's Allegheny National Fish Hatchery) are available from wild Seneca lake trout. However, the large number of wild-caught parents (103 males and 39 females) that produced the spawn for our Seneca Lake samples suggests that the observed lack of variability in the hatchery progeny is representative of the wild population as well.

Because of such low inherent variability (nearly 9 out of 10 lake trout will be homozygous at any of the polymorphic loci), chances are high of losing variability when lake trout are obtained for brood stock. Maintenance of large effective population sizes and outbreeding, or periodic infusion of genes from wild populations, are the two most important ways to preserve genetic variability in hatchery strains of lake trout. The exact number of parents needed may be as few as 30 of each sex, but is more likely to exceed 100. Regular monitoring of genetic variability should also be included in any program based on the above considerations. In this regard, gel electrophoresis is still the best method available for quantifying overall genetic variability, either within or between strains.

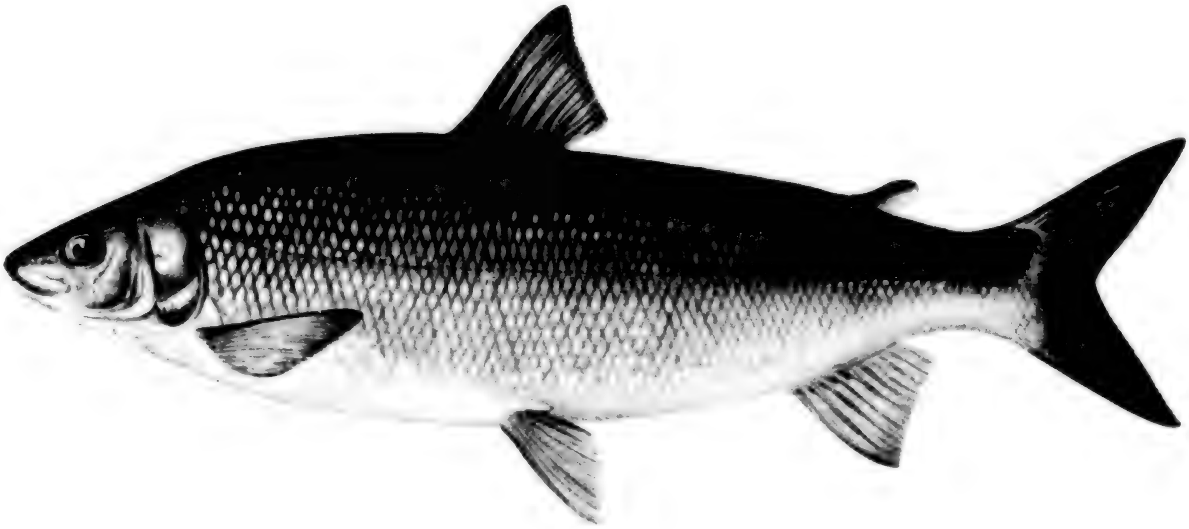
Thomas N. Todd

> ***"Maintenance of large effective population sizes and outbreeding, or periodic infusion of genes from wild population, are the two most important ways to preserve genetic variability in hatchery strains of lake trout."***

Feasibility of Mass Culturing Coregonines and Reestablishing Damaged Populations in the Great Lakes

A review of U.S. Fish Commission documents from the years 1872 to 1940 has revealed that the U.S. Government stocked nearly 10 billion lake whitefish fry and provided about 2.5 billion eggs for rearing by state authorities or foreign governments. Other species of coregonines cultured for stocking purposes by the U.S. Fish Commission included Coregonus albula, C. artedii, C. wartmanni, and Prosopium williamsoni. Most fry and eggs were destined for the Great Lakes where, despite high optimism, stocking efforts seem to have been largely unsuccessful. However, there are tantalizing references in the Fish Commission Reports to successful whitefish plants in other regions. These references, in addition to a predominantly European literature on coregonine culture and stocking, are being reviewed to determine how to create or substantially augment coregonine populations in the Great Lakes by using piscicultural techniques.

Thomas N. Todd



Lake Whitefish

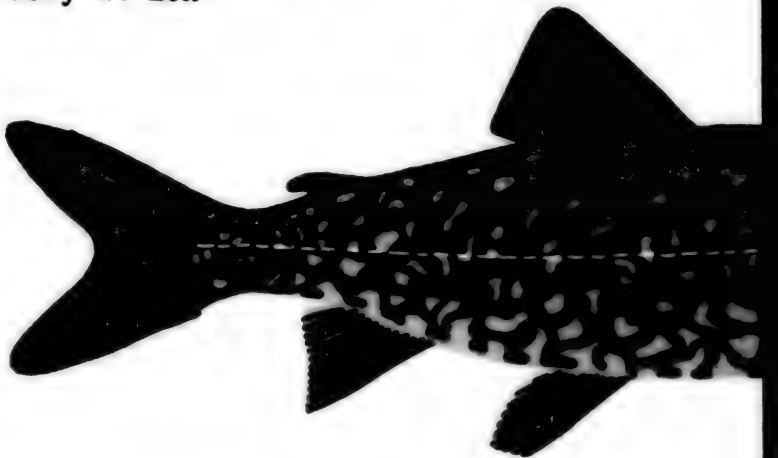
Simulation of Predator-Prey Systems in Lake Michigan

Forage provided by alewives is the key in sustaining stocks of coho and chinook salmon, brown and rainbow trout, and lake trout at current levels of abundance in Lake Michigan. Thus, before attempting to expand the sizes of these salmonid populations by increasing stocking rates, serious consideration should be given to the capacity of the alewife population to withstand increased predation. The adult component of the alewife population (age II and older) may be especially sensitive to higher predation rates because most salmonids feed heavily on adult alewives throughout most of their lives. Indeed, the availability of adult alewives may well be the major limiting factor of salmonid carrying capacity in Lake Michigan.

On the basis of estimated biomasses of adult alewives from 1973 through 1979 and on annual mortality rates imposed thereon by fishing, impingement at water intakes, and predation by salmonids other than lake trout, we estimated that Lake Michigan can support a maximum lake trout population (age II and older) of about 20,000 metric tons (provided that the other sources of mortality do not change). If this preliminary estimate is reasonable, the present size of the adult lake trout population could be substantially increased--an interesting possibility that should allay the concerns of many investigators who believe that much larger spawning stocks are necessary before the planted lake trout can become fully self-sustaining.

We also completed a number of analyses on the dynamics of the alewife population itself. This analytical work produced a Ricker-type stock-recruitment relation for 1968-76 that indicated a high degree of density-dependent regulation of population size, and yielded more definitive information on seasonal changes in mean bodyweight or condition of alewives at given reference lengths, which directly influence biological production.

Edward H. Brown, Jr.
Gary W. Eck



Development and Evaluation of Management Strategies for Great Lakes Fisheries Resources

In cooperation with other members of the Lake Michigan Committee's Lake Trout Technical Committee, we presented a technical report on lake trout rehabilitation at the annual meeting of the Lake Michigan Committee in Milwaukee. This report examined various biological, regulatory, and management factors that affect the attainment of a self-sustaining lake trout population theoretically able to yield 1,134 t (2.5 million pounds) annually on a sustained basis to all user groups combined. The most immediate impediment to achieving this theoretical sustained yield--projected the Lake Committee's 1980 meeting--appears to be the continuing high rate of removal of planted lake trout, very conservatively estimated at 279,000 fish weighing 632 t (1.4 million pounds) in 1979. These widespread removals contributed, for example, to the high total mortality estimates that ranged from 47% in east-central Lake Michigan to 65% in northern Lake Michigan waters during 1979. Studies reported in the literature indicate that a total annual mortality rate of 50% is near the maximum that self-replenishing lake trout populations can withstand.

Data submitted by Ohio, Michigan, Ontario, and the Laboratory's Lake Erie Project were used to estimate the standing stock and total allowable harvest of walleyes in the western basin of Lake Erie in 1981. This information was provided to the Walleye Task Group of the Great Lakes Fishery Commission's Standing Technical Committee on Lake Erie for presentation at the 1981 spring meeting of the Lake Erie Committee. Indications that the 1980 year class is second in size only to that of 1977 among those of the past 15 years is cause for continuing optimism over recovery of this resource. Indeed, based on sequential projection methods developed earlier, we predict a fishable stock (consisting of fish at least 14.5 inches long) of nearly 26 million fish in 1982 in western Lake Erie.

Edward H. Brown, Jr.
Richard W. Hatch

Courtesy of Great Lakes Fishery Commission

Ecology and Limnology

Three developments have collectively caused the decline or impeded the rehabilitation of desirable native fishes and, in some areas, caused an increase in the abundance of other less-desirable species: (1) over-fishing of some species; (2) water-use practices that lead to deterioration and destruction of critical fish habitat, particularly to spawning and nursery areas in nearshore waters; and (3) the introduction of undesirable exotic fishes, including the sea lamprey. If not halted or controlled, such abuse of the aquatic environment will continue to impede the restoration and impair the productivity of Great Lakes fishery resources.

Multiple-purpose use of the Great Lakes--for navigation, as a municipal and industrial water supply, and for the final dispersion of the basin's water-borne wastes--poses a poorly quantified but increasingly serious threat to the habitat and productivity of Great Lakes fishes. Maintenance of waterways, for example, is expected to entail the annual dredging and redeposition of as much as 12 million cubic yards of lake bottom materials by 1985, with relatively unknown effects on the health of fish stocks. Water use by the electric-power generating industry by the turn of the century may exceed 1 or 2% per day of the total volume of the nearshore waters of the Great Lakes, and destruction of fish in these waters will approach 100% in some situations. Research projects in this section of the Laboratory's program describe the effects of these and other water-use practices on fish and their habitat so that less destructive methods of water withdrawal and physical alteration can be developed.

Thomas A. Edsall, Section Chief

Nutrient Cycling and Plankton-Benthos Productivity

Bruce A. Manny, Project Leader

Effects of Increased Nutrient Loading on Fish Spawning and Nursery Habitat in Great Lakes Nearshore Waters

Self-sustaining stocks of lake trout, once found at many locations throughout the Great Lakes, are now present only in Lake Superior. Various hypotheses have been advanced to explain why this species disappeared from much of its former range in the Great Lakes, including overfishing, predation by sea lampreys, and degradation of spawning and nursery habitat. One such hypothesis states that increased nutrient loading accelerates the production of plankton and benthic algae that subsequently degrade interstitial waters on spawning grounds when they settle and decompose. This hypothesis may partly explain why lake trout have also failed to reestablish themselves. To test this hypothesis, we initiated a limnological investigation at four locations used historically for spawning by lake trout in nearshore waters of western Lake Huron: North Graham Shoal in the Straits of Mackinac, Bell Shoal near Rockport, North Point near Alpena, and Point Au Gres in Saginaw Bay. These locations lie along a recently described north-south gradient in water quality that has developed since native lake trout stocks last spawned successfully in the area. Measurements of nutrient concentrations in the water column, chlorophyll content and biomass of the plankton, and 5-day biological oxygen demand of the sediments were made over rock-rubble substrate at each of the four locations in October 1981. Macrozoobenthos were also sampled to provide a biotic index of water quality, and sediment traps were deployed at each location to determine how much sediment settles on the spawning grounds when eggs and sac-fry would be present.

Preliminary analysis of the data revealed that the biological oxygen demand of the sediments at Point Au Gres (24 mg/l) was about 7-10 times higher than at the other three locations (2.5-3.7 mg/l). This high sediment oxygen demand could adversely affect egg survival at Point Au Gres during winter when the lake surface freezes and water movement through interstitial spaces in the substrate around the eggs is reduced. Measurements of dissolved oxygen and sulfide concentration scheduled to be made in interstitial waters of the substrate at these locations during the winter of 1981-82 will more firmly establish whether water quality is preventing or impeding reestablishment of self-sustaining stocks of lake trout on historically used spawning and nursery grounds in nearshore U.S. waters of Lake Huron. We anticipate that the results of this investigation will also provide a basis for determining whether water quality objectives established for nearshore Great Lakes waters will be adequate to permit the reestablishment of self-sustaining stocks of lake trout in those waters.

Bruce A. Manny

Productivity of Aquatic Macrophytes and Associated Periphyton in the St. Clair-Detroit River Ecosystem

Studies were conducted from 1978 to 1980 in Anchor Bay of Lake St. Clair to document the distribution, abundance, species composition, and production of submersed aquatic macrophytes in the bay. These studies were designed to provide information needed to estimate the contribution of submersed aquatic macrophytes to the productivity of the fish communities in the St. Clair-Detroit River ecosystem. A preliminary survey of Anchor Bay in 1978 showed that submersed macrophytes were confined to the shallow waters around the perimeter of the bay, and that only scattered beds of a benthic alga (Chara) were present in deeper, open waters. The survey in 1978 also indicated that the submersed macrophyte communities in Belvidere Bay, Muscamoot Bay, and at Sand Island were representative of those present elsewhere in the littoral waters of Anchor Bay. As a result, studies in 1979 and 1980 were performed only in Belvidere Bay, Muscamoot Bay, and at Sand Island. Of the 24 species of macrophytes we identified in 1979-80, water stargrass (Heteranthera dubia) was the most common macrophyte in Belvidere Bay; Eurasian watermilfoil (Myriophyllum spicatum), waterweed (Elodea canadensis) and naiad (Najas flexilis) dominated the flora in Little Muscamoot Bay; and M. spicatum was the most common macrophyte at Sand Island. In 1979, the seasonal dry weight biomass was highest in Belvidere Bay in August (134 g/m^2), and in Little Muscamoot Bay and at Sand Island in September (93 and 72 g/m^2, respectively). Although these values are lower than the average value (152 g/m^2), we calculated from the literature for submersed macrophyte densities in other lakes with similar water chemistry at this latitude, preliminary evaluation of our data indicates that the submersed macrophyte beds in our three study areas were dense enough to provide young fish with cover and feeding opportunities that were not present in adjacent macrophyte-free areas.

Bruce A. Manny
Charles L. Brown

Distribution and Abundance of Macrozoobenthos in the St. Clair-Detroit River Ecosystem

In 1979, we conducted a study in Lake St. Clair to determine if the distribution and abundance of benthic invertebrates in beds of submersed aquatic macrophytes differed from that in adjacent macrophyte-free areas. A total of 238 bottom samples were collected in Belvidere Bay, Little Muscamoot Bay, and at Sand Island. At each of these three locations, we sampled benthos in areas that supported macrophytes and in adjacent macrophyte-free areas. Analysis of our samples revealed that although preference for submersed vegetation as a substrate was not universal among all organisms, a number of crustaceans that are important in the diet of fishes were most abundant among beds of macrophytes we sampled. For example, in Belvidere Bay, the amphipod Hyalella was more abundant among vegetation than in adjacent vegetation-free areas. Similarly, the isopod Asellus and snails (Gastropoda) were more abundant among stands of submersed macrophytes than in adjacent macrophyte-free areas at all three sampling locations. All of these taxa were represented in the diets of yellow perch we caught at these locations. Therefore, if beds of submersed macrophytes were disturbed or eliminated in these waters, the relative abundance of these macrozoobenthic taxa would decrease and the food of yellow perch and perhaps other fishes would be reduced.

Jarl K. Hiltunen
Bruce A. Manny

Ecological Effects of Rubble Mound Breakwall Construction and Channel Dredging at West Harbor, Ohio (Western Lake Erie)

The U.S. Army Corps of Engineers is undertaking a breakwall construction and channel-dredging project at West Harbor in Western Lake Erie to facilitate use of the harbor by small recreational craft. Breakwall construction and dredging began in August 1981 and are scheduled to be completed in about a year. In response to a request from the Corps' Coastal Engineering Research Center, we are conducting a Corps-funded, before-and-after study at the construction site to determine the effect of that project on the nearshore aquatic environment.

In August, we completed the first of 10 scheduled fishery and limnological surveys at the West Harbor site. We collected macrozoobenthos and fish, and measured turbidity, suspended solids, water temperature, and dissolved oxygen at stations located on the 0.5-, 2-, 3-, and 4-m depth contours of each of five transects extending lakeward from the shoreline. Transects I and V are reference or control transects, about 1 km northwest and southeast, respectively, of the entrance to West Harbor. Transects II and IV are about 300 m northeast and southeast, respectively, of Transect III, which lies in the existing natural channel connecting the harbor with the deeper offshore waters. One breakwall will be constructed between Transects II and III and the other will be constructed between Transects III and IV; the new harbor channel will be dredged to a depth of 3 m along Transect III.

Preliminary analysis of the data collected during the first survey indicated that turbidity and suspended particulate matter were higher at the nearshore stations (8-25 NTU and 12-41 mg/l, respectively) than at the offshore stations (4-8 NTU and 9-13 mg/l, respectively) on all transects, and that dissolved oxygen concentrations were slightly lower at the surface (9.2-11.2 mg/l) than at the bottom (9.3-11.6 mg/l) at nearly all stations. The diversity (17 taxa) and density of macrozoobenthos (75-19,574/m^2) in the fine sand and silts throughout the study area were low; the most common taxa in the samples were oligochaetes (500-5800/m^2), chironomid larvae (45-860/m^2), and the polychaete Manayunkia speciosa (up to 16,700/m^2). Sampling with beach seines and bottom trawls yielded 11,500 fish representing 20 species. White bass and gizzard shad together made up 87% of the total catch, six other species each composed 1-5%, and the remaining 12 species each contributed less than 1%. Young-of-the-year fish made up 96% of the catch, indicating that the construction site is located in an area that serves as a nursery ground for at least nine fish species.

Bruce A. Manny

Atlas of Aquatic Plant Communities in the St. Clair-Detroit River Ecosystem

Distribution maps of submersed macrophyte habitat are needed to inventory and catalog the extent of remaining aquatic plant resources in the St. Clair-Detroit River ecosystem and to estimate the rate at which they are being lost. The production of maps from ground survey information is costly and imprecise, but a survey of the literature indicated that low-altitude aerial photography would probably be an economical and reliable method for mapping the distribution of submersed plants in this ecosystem. To test the feasibility of this approach, we conducted a preliminary low-altitude aerial survey in September 1978 at 12 sites where we had already collected ground survey information on the composition of submersed aquatic vegetation.

Using the low-altitude, 1:5000 scale, color photographs from the aerial survey and collateral ground truth information, we developed written criteria that we believed could be applied to assist photointerpreters to distinguish correctly images of submersed macrophyte beds from other images on the photographs and to identify the macrophyte taxa present. We then provided these criteria and a set of typical photographs to various test subjects, including some who were trained in photointepretation, some who had field experience with submersed aquatic macrophytes in the St. Clair-Detroit River system, and others who had no such training or experience. The test results revealed that the criteria we developed could be applied equally well by the test subjects irrespective of their previous training and experience; they also showed that these subjects were able to identify submersed macrophyte beds and the macrophyte taxa present with accuracy rates of about 96 and 68%, respectively. We believe these results demonstrate that low-altitude aerial photographic surveys, together with limited amounts of collateral ground truth data, could be used to provide economical and reliable maps of submersed aquatic vegetation in littoral waters of the Great Lakes.

Bruce A. Manny
Donald W. Schloesser

Effects of Water-Use Practices

Thomas P. Poe, Project Leader

Abundance and Distribution of Phytomacrofauna and Zooplankton, and Their Use as Food by Young Fish in the Nearshore Waters and Contiguous Wetlands of Lake St. Clair

Aquatic macrophytes, and the phytomacrofauna and zooplankton usually found in association with them, are generally recognized as important in the production of fishes in many littoral habitats. Despite the fact that human water use practices such as dredge-and-fill operations and shoreline bulkheading have destroyed much of the macrophyte habitat in the Great Lakes and pose a threat to the rest, no research has been done to define the contribution of aquatic macrophytes and their associated invertebrate fauna to fish production in the Great Lakes. To provide a basis for estimating their contribution to fish production in Lake St. Clair, we collected over 1,100 samples of phytomacrofauna, zooplankton, and young fish from macrophyte beds and from adjacent macrophyte-free areas in three locations in the lake in 1979. These locations, described in the preceding section, were Muscamoot Bay, Sand Island, and Belvidere Bay.

Analyses of the invertebrate samples and the stomach contents of over 430 yellow perch of ages 0-II revealed that the invertebrates were usually more abundant in the macrophyte stands than in the macrophyte-free areas; that the yellow perch had fed almost exclusively on invertebrates; and that the most intensive feeding had occurred in areas where the invertebrate prey was most abundant. These results indicate that aquatic vegetation plays an important role in the feeding ecology of young yellow perch in Lake St. Clair, and contributes significantly to fish production in that water body.

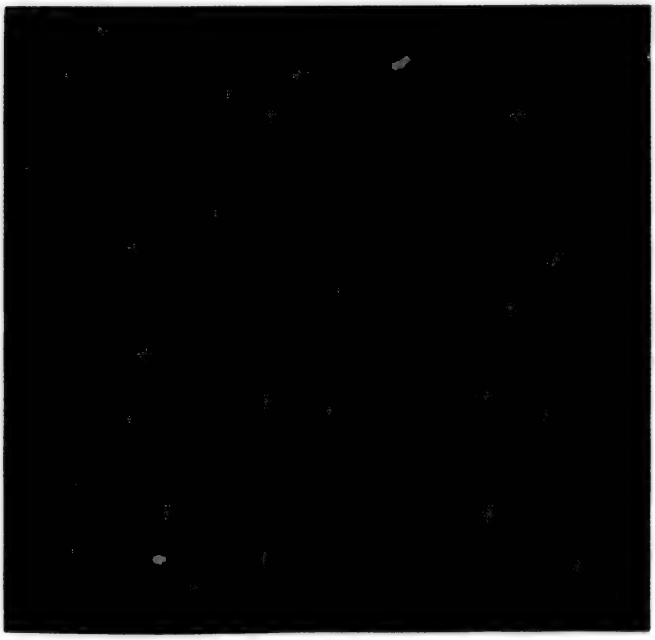
Thomas P. Poe
Donald W. Schloesser
Charles L. Brown

Evaluation of Fish Spawning and Nursery Habitat in Great Lakes Nearshore Waters

The reestablishment of self-sustaining stocks of lake trout and lake whitefish in the U. S. waters of Lake Huron would be facilitated if information were available to show which portions of the spawning and nursery habitat used historically by those two species is still capable of supporting the production of viable, swim-up fry. This information would provide improved guidance for the ongoing Lake Huron brood stock rehabilitation program by pinpointing the best sites where lake trout stocking efforts could be focused and where refuges designed to protect the brood stocks of both species could be established. This information would also aid in the development of explicit strategies designed to protect the remaining potentially productive spawning and nursery habitat from the adverse effects of various water-use practices (e.g., disposal of municipal and industrial wastes, navigation related lakebed alterations, offshore hydrocarbon development) and to mitigate effectively additional, unavoidable losses of that specialized habitat (e.g., by creating rubble-mound structures in areas with suitable water quality to replace lost or degraded areas of spawning substrate).

"Cobblestone" substrate.

Tom Poe



During fall 1981, we began a study in the nearshore waters of northern Lake Huron near Rockport, Michigan, to investigate the feasibility of using an underwater television camera to survey historically-used lake trout and lake whitefish spawning and nursery habitat and to evaluate its present potential to produce viable swim-up fry. Images of the substrate were recorded on videotape at several locations where we were able to collect fertilized eggs of lake trout and whitefish from the lake bottom by pumping. Preliminary study of these video tapes indicated that a variety of substrates are present in these areas. The substrate at a reef near the entrance to Rockport Harbor were lake trout spawned consisted primarily of loose, angular rock ranging from 30 to 200 cm in diameter. This rock was sorted vertically by size, with the larger pieces overlying the smaller ones. In other portions of the reef, loose rock rested on shelf rock. The portions of the reef where the substrate displayed vertical sorting appeared to provide the most extensive refuge for developing eggs and newly hatched fry. The substrate at Middle Island where we loose rock from 0.5 to 300 cm in diameter. More than 50% of this rock was "honeycombed rock," which historically has been reported as a preferred spawning substrate for lake trout and whitefish.

Thomas P. Poe
Robert T. Nester

The Structure and Productivity of Fish Communities in the St. Clair-Detroit River Ecosystem as Affected by Shoreline Erosion and Riverbed or Lakebed Modification

The St. Clair and Detroit Rivers and Lake St. Clair contain a diverse and productive fish community that supports a valuable recreational fishery in the urban Detroit area. The high productivity of this fish community has been attributed to the high quality of the water entering the system from Lake Huron and to the presence of dense stands of aquatic vegetation that are a prominent feature of major portions of the system. These macrophyte stands are believed to contribute substantially to fish production by providing substrate and detritus in quantities needed to support the macroinvertebrates in the system upon which fish feed intensively. Concern about the continuing loss of aquatic macrophyte habitat as a result of shoreline dredging, bulkheading, and backfilling throughout the system--particularly in Lake St. Clair--induced us to begin a study in 1979 to determine the impact of human shoreline and lakebed modification practices on the macrophyte and fish communities in the shallow, nearshore waters of Lake St. Clair.

In 1979-80, we sampled fish with a 16-foot bottom trawl and 140-foot graded mesh gillnets at three locations in Anchor Bay, Lake St. Clair. Sampling locations were in Muscamoot Bay, an area of unmodified lakebed and shoreline populated with dense stands of emergent and submersed macrophytes; at Sand Island, a semi-riverine area that has been subject to minor shoreline and lakebed modification and contains moderately dense stands of emergent vegetation and submersed macrophytes; and in Belvidere Bay, an area with an intensively modified shoreline and a lakebed that supports sparse stands of emergent vegetation and dense stands of submersed macrophytes.

The composition of the fish community was distinctly different at each of the three sampling locations. The dominant species in trawl catches, in order of abundance at each location, were as follows: Belvidere Bay--rock bass, pumpkinseed, yellow perch, and bluegill; Muscamoot Bay--yellow perch, bluntnose minnow, spottail shiner, and banded killifish; and Sand Island--alewife, yellow perch, spottail shiner, smelt, and logperch. In gillnet catches, the dominant species were as follows: Belvidere Bay--yellow perch, alewife, gizzard shad, carp, and pumpkinseed; Muscamoot Bay--yellow perch, alewife, longnose gar, northern pike, and carp; and Sand Island--yellow perch, spottail shiner, alewife, walleye, and northern pike. These differences in the composition of the fish community among the three locations studied reflect both natural and man-made differences in the character of the habitat at these locations. Our sampling also revealed that fish were more abundant in Belvidere Bay than at the other two locations. Although the shoreline in Belvidere Bay is more severely altered than that in the other two areas, so that the loss of the emergent macrophytes in Belvidere Bay is nearly complete, the lakebed is not altered significantly and greater numbers and biomass of submersed aquatic macrophytes are present there than at the other two locations. These results suggest that submersed vegetation is more essential than emergent vegetation to the maintenance and productivity of the fish communities in Anchor Bay.

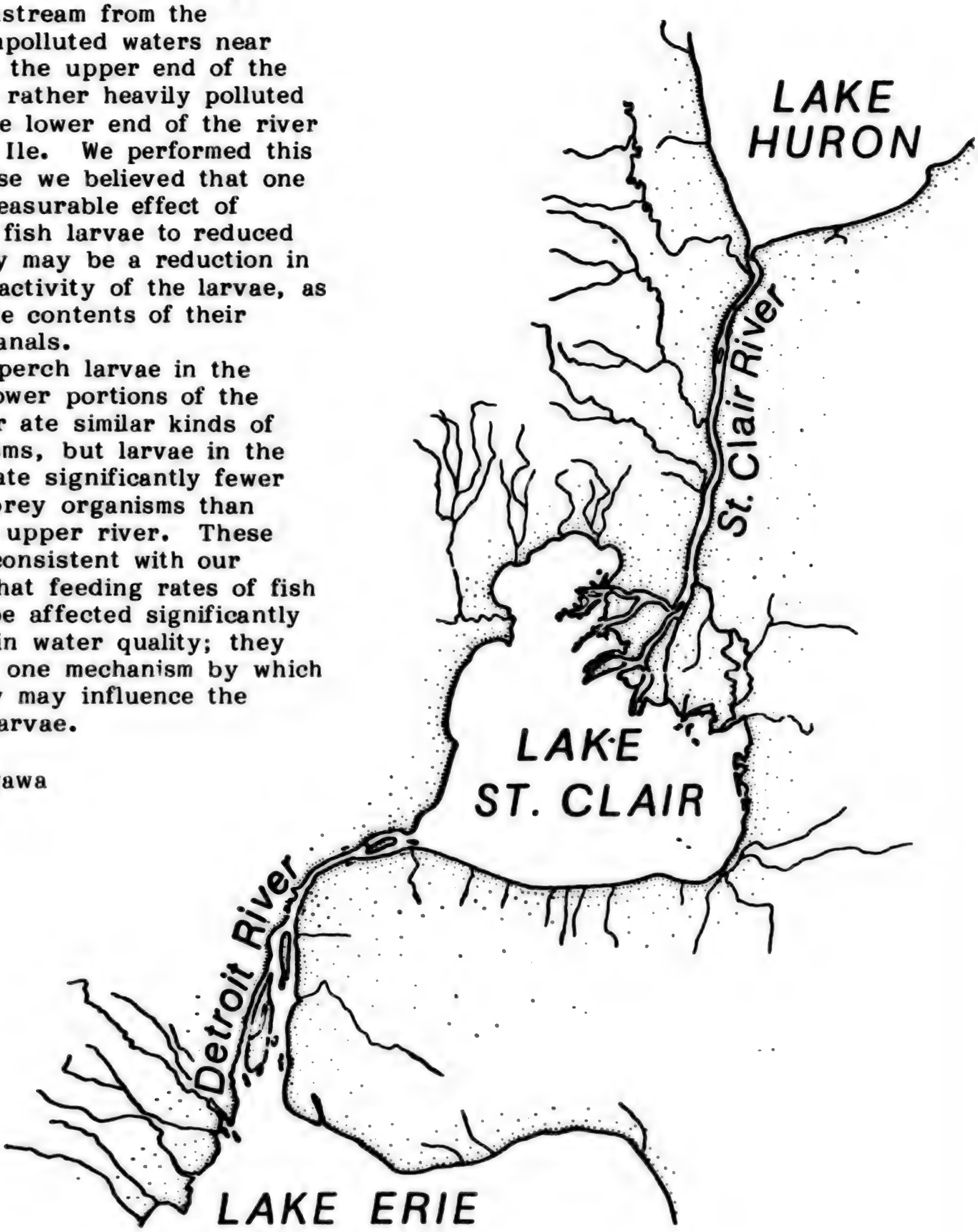
Charles O. Hatcher

Food and Feeding of Larval Fish in the St. Clair-Detroit River Ecosystem

We studied the food habits of over 900 larval yellow perch collected from the Detroit River in 1977-78 to determine if there were changes in the kinds and amounts of food ingested by the larvae as they passed downstream from the relatively unpolluted waters near Belle Isle at the upper end of the river to the rather heavily polluted waters at the lower end of the river near Grosse Ile. We performed this study because we believed that one sensitive, measurable effect of exposure of fish larvae to reduced water quality may be a reduction in the feeding activity of the larvae, as shown by the contents of their alimentary canals.

Yellow perch larvae in the upper and lower portions of the Detroit River ate similar kinds of prey organisms, but larvae in the lower river ate significantly fewer ($\underline{P} \leq 0.05$) prey organisms than those in the upper river. These results are consistent with our hypothesis that feeding rates of fish larvae may be affected significantly by changes in water quality; they also suggest one mechanism by which water quality may influence the survival of larvae.

Roann E. Ogawa



Effects of Beach Nourishment on the Nearshore Waters of Lake Huron Adjacent to the Lexington (Michigan) Harbor of Refuge

In 1980, the U. S. Army Corps of Engineers conducted a beach nourishment project at the Lexington (Michigan) Harbor of Refuge on Lake Huron to mitigate shore erosion attributable to the installation of that federal navigation-related structure. The nourishment activity involved depositing beach sand at or near the water line along the eroded shore. In response to a request from the Corps' Coastal Engineering Research Center, we conducted a Corps-funded, before-and-after study to determine the effect of the project on the nearshore aquatic environment. We sampled benthic macroinvertebrates, fish, and substrate, and made limnological measurements (turbidity, suspended solids, temperature and dissolved oxygen) on six different occasions at the 0.5-, 2-, 3-, and 4-m depth contours along six transects extending out from the shoreline. Three of the transects were in the "fill" or nourishment area, one was at the "borrow" site where nourishment material was removed, and two others were in reference areas believed to be outside the direct influence of the nourishment activity.

The effects of the Corps' beach nourishment activity on water quality and sediment particle size distribution in the study area were minor. A temporary increase in turbidity was noted during the dredging, but levels soon returned to normal when dredging ceased. Sediment particle size composition was dominated by fine sand at almost all stations and transects before and after nourishment. A preliminary analysis of the other data collected suggests that no significant changes have occurred in the biota of the study area as a result of beach nourishment activities. The abundance of macrozoobenthic organisms at the three transects in the nourishment area decreased slightly after nourishment materials were deposited, but no other changes in the macrozoobenthos were observed. Changes observed in the beach seine and gillnet catches throughout the survey can probably be interpreted as normal, random, or seasonal variation and not as a response to the beach nourishment activities.

Robert T. Nester

Studies conducted by researchers will determine how rapidly a new breakwater is colonized by attached invertebrate organisms and to what extent it provides spawning and nursery habitat for fish.

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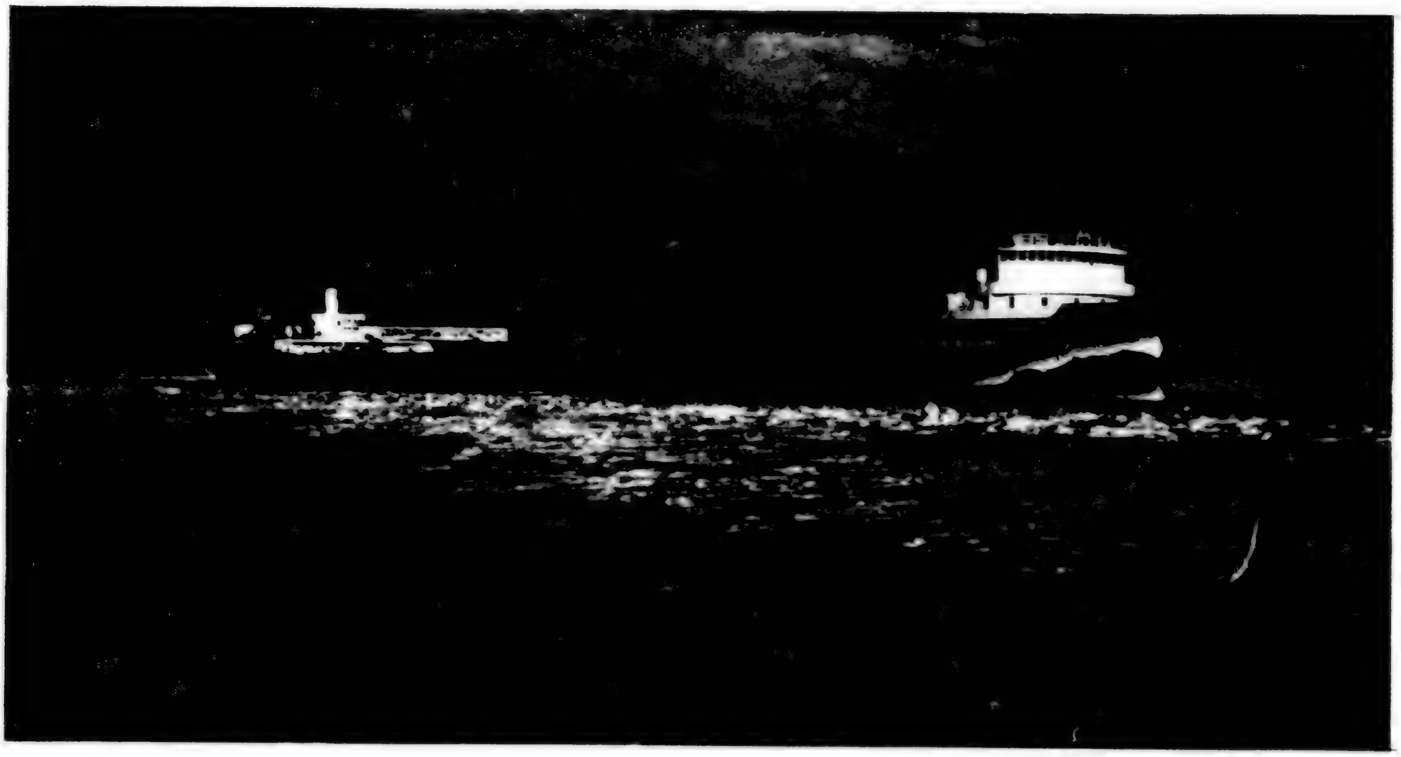
Great Lakes Environmental Studies—Winter Navigation



Atlas of the Spawning and Nursery Areas of the Great Lakes Fishes

An 1,100 page draft atlas prepared under contract for the Army Corps of Engineers was submitted to that agency for review. The atlas was prepared as a 13 volume set with individual volumes covering each of the five Great Lakes, Lake St. Clair, and the five Great Lakes connecting waters. Volume 12 describes the reproductive characteristics of the 117 fish species covered in volumes 1-11, and volume 13 contains literature citations. The material in each of the first 11 volumes is presented in narrative form, by species. Each species narrative is also accompanied by a map when sufficient information existed to warrant it.

This atlas represents the culmination of an intensive effort to consolidate existing information describing spawning and nursery areas used by stocks of fish, including anadromous stocks, considered to be residents of the Great Lakes and their connecting waters. The information presented for each documented (or suspected) spawning or nursery area identified in the atlas includes, when known, the area's precise location, history of use, season of use, water temperature during the season of use, major substrate type, and water depth. Pre- and post-spawning migrations of mature fish and movements of young fish are also described, insofar as this information serves to better delineate spawning or nursery areas. Concise descriptions of what are perceived to be the general spawning and nursery requirements of the more common Great Lakes fishes were compiled from the literature and are also presented.

Thomas A. Edsall
Carole D. Goodyear

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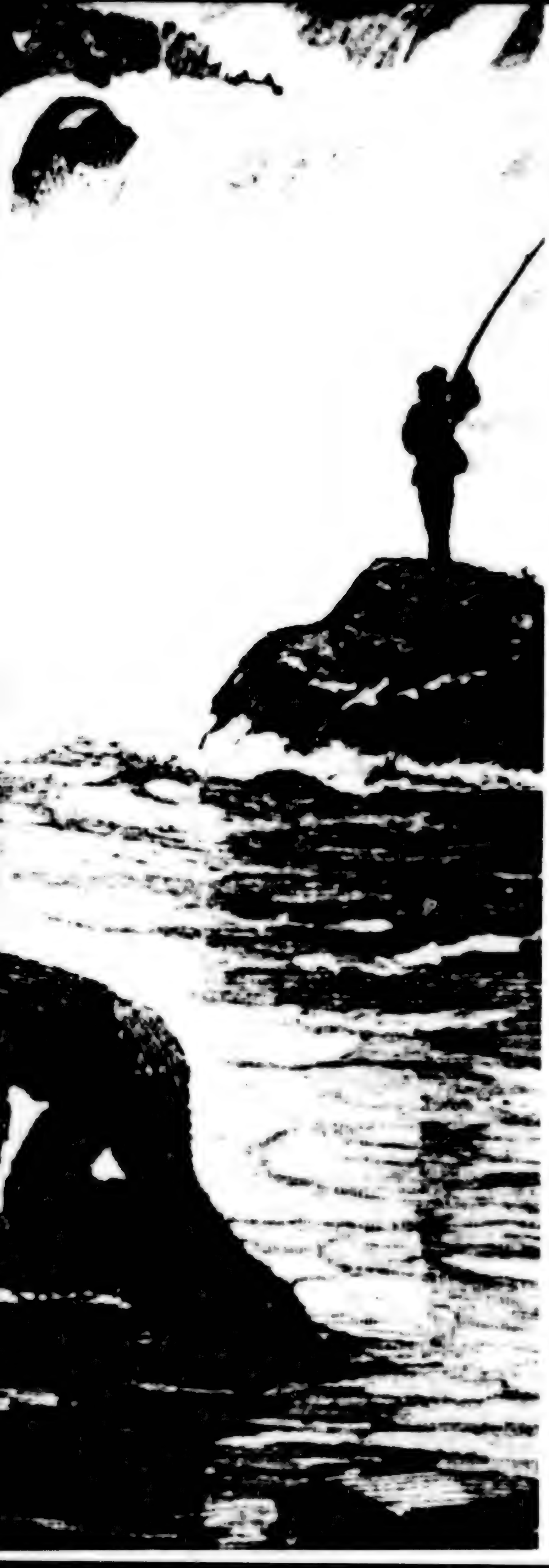


Courtesy of Great Lakes Fishery Commission

Physiology and Contaminant Chemistry

Changes in the physical, chemical, and biological characteristics of the Great Lakes--natural changes as well as those induced by man's use of the lakes--all affect in subtle and often adverse ways the productivity of the lakes' fishery resources. Future protection and management of these resources depend on our ability to measure and predict the effects of environmental changes. Prerequisites for making these predictions for Great Lakes fishes are determinations of their normal physiological and behavioral characteristics, and our interpretation of how environmental changes alter them. The aim of research performed in this section is to provide this information by means of controlled experiments. Particular emphasis is placed on spawning requirements, survival of early life stages, and forage needs of important species.

Among the more dramatic environmental changes documented in the Great Lakes during recent years are those resulting from chemical contamination. This contamination threatens the aquatic environment, fish, and fisheries of the Great Lakes. Residues of toxic substances such as DDT and its metabolites, dieldrin, polychlorinated biphenyls (PCBs), mercury, and several other pesticides, industrial organics, and metals are common in fish. Major goals of two projects administered by this section are to describe the kinds and amounts of chemical contamination in the various species, to determine possible effects of known contaminants (both singularly and in combination) on living resources of the lakes, to describe the dynamics of these toxic substances including evaluation of conditions or activities that influence their bioavailability, and finally to assess the effectiveness of past enforcement actions in reducing contamination.

Wayne A. Willford, Section Chief

Physiology and Behavior

Neal R. Foster, Project Leader

Role of Olfactory Cues in the Reproduction of Lake Trout

Current interagency efforts to rebuild lake trout populations in the Great Lakes consist of massive plantings of hatchery-reared fish at selected nearshore and offshore locations. By the target date of 1986, it is hoped that 50 percent of the lake trout populations will have been produced in the wild. For populations to reproduce in the wild, however, mature planted fish must be able to locate and use breeding grounds where their own offspring will hatch, survive swim-up and first feeding, and return eventually as spawning adults themselves.

Odors deposited in the substrate by YOY lake trout were shown in our previous tests to serve as a possible mechanism facilitating the subsequent location of breeding areas by adults. These tests demonstrated an apparent association between the location of stationary odor sources containing feces and sloughed mucus from recently hatched fry (odors which one would expect to be present at an actively used spawning and nursery site) and subsequent spawning site selection by sexually ripe lake trout in a large circular indoor pool.

In fall 1980, we repeated these experiments to confirm our earlier observations and to compare the frequency and location of specific behaviors. We used adult trout in two smaller behavior observation pools, one where fry feces and mucus were present and the other where such odor sources were absent. No spawnings were obtained in either pool because conditions precluded proper control of brood stock ripening in the laboratory. Nevertheless, the single test odor source did have a significant attractant effect as measured by the frequency of specific behaviors over each of the four "reefs" in the two pools. The results of these experiments further support the hypothesis that odors deposited by recently hatched lake trout fry function as attractants during subsequent spawning site selection by adult lake trout.

Neal R. Foster
William H. Berlin
Daniel V. O'Connor
Paul E. Polanski

Physiological and Behavioral Differences in Lake Trout Strains

In previously published studies, investigators found significant differences in post-planting survival, buoyancy regulation, fat deposition, and spawning times among hatchery-reared lake trout obtained as eggs from various wild stocks or hatchery strains. Similarly, the purpose of this study was to compare selected physiological and behavioral characteristics among laboratory-reared lake trout from different native stocks or hatchery strains. These traits presumably are associated with adaptation to environmental variables such as temperature, light intensity, depth, and bottom substrate type, and are ultimately tied to a fish's performance and survival.

We conducted laboratory comparisons of lake trout obtained as eggs or fry from four sources: Marquette Hatchery (Michigan); Gull Island Shoal (Lake Superior); Clearwater Lake, Manitoba; and Seneca Lake, New York. We also tested lake trout hatched from eggs of the siscowet from Lake Superior. In early life history studies, we found a shorter incubation period and a longer interval between hatching and swim-up in fry of siscowets than in fry from the Marquette Hatchery or Gull Island Shoal strains. Growth and survival comparisons among siscowet fry, Gull Island Shoal fry, and Marquette Hatchery fry showed that survival of Gull Island Shoal and Marquette Hatchery fry was better at 4° and 10° C than survival of siscowet fry. The differences in survival were particularly evident at 10° C where only 36% of the siscowets survived during the 6-month study, whereas 73% of the Gull Island Shoal fry and 78% of the Marquette Hatchery fry survived. When reared at the two temperatures on an ad libitum diet, all fry grew much faster at 10° C than at 4° C. Similar rates of growth were observed among surviving fry from each of the three sources at each of the two rearing temperatures.

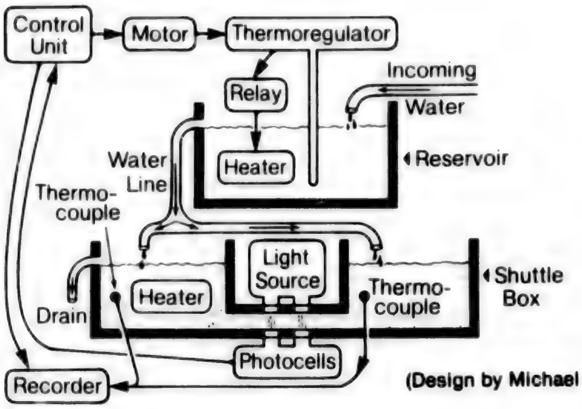
> ***"Observations suggested subtle, yet consistent differences in activity level, response to overhead shadows, and feeding rate among the three strains."***

To determine whether any consistent behavioral differences existed among siscowet, Gull Island Shoal, and Marquette Hatchery strains of lake trout, we placed five 2-year-old fish of each of these strains in separate compartments of a "living stream" unit to permit side-by-side comparisons. Observations suggested subtle, yet consistent differences in activity level, response to overhead shadows, and feeding rate among the three strains. The siscowets were the most sedentary of the three strains--at any given time 2 or 3 of the 5 siscowets were resting directly on the bottom while all of the Gull Island Shoal and Marquette Hatchery trout were usually actively swimming off the bottom. The Marquette Hatchery trout, reared under the same conditions as the other two strains, were the most skittish in the abruptness and intensity of their response to shadows of hand movements over the tank; the Gull Island Shoal fish were less so, and the siscowets were least skittish of all. The siscowets fed most voraciously, consuming pelleted food in less than half the time required by the other two strains.

Neal R. Foster
Paul E. Polanski
William H. Berlin

Temperature Preference of Different Lake Trout Strains

Various strains of lake trout have been planted in the Great Lakes, and field observations of post-planting depth distributions of two strains--Marquette Hatchery (Lake Superior Lean) and Clearwater Lake, Manitoba--in Lake Ontario suggest that these strains have different preferred temperatures. Since temperature preferences of different strains of lake trout may have important implications for possible strain-specific growth rates and other temperature-dependent processes in the lake environment, we have initiated a new study (to some extent a development from our previous research on strain comparisons) to determine experimentally if significant differences in temperature preference exist among different strains of lake trout reared under identical laboratory conditions. We will use temporal thermal gradient shuttleboxes to compare temperature preference among Marquette, Clearwater Lake, and Seneca Lake lake trout, all of which have been planted in Lake Ontario. Experimental fish will be maintained on the same ration to avoid the known confounding effects of interaction between ration size and temperature preference.



(Design by Michael Mac)

Fig. 2 - Shuttlebox design

Neal R. Foster
Paul E. Polanski

Isolation and Identification of Attractant Pheromones in Lake Trout

Recent behavioral and electrophysiological experiments conducted at the Institute of Zoophysiology, University of Oslo, Norway, demonstrated the presence of potent attractant odors in intestinal contents of smolts of the Arctic char (Salvelinus alpinus, a close relative of the lake trout). We have undertaken a new study to attempt to replicate these results in lake trout and as an outgrowth of other studies of olfactory cues.

In fall 1981, we placed adult lake trout in two 10,000-liter circular behavior observation pools and placed stationary odor sources containing fry odors on one of two "reefs" in each pool. Male nuptial coloration and courtship behavior subsequently developed in both pools and nocturnal observations (videotaped) suggested greater male activity at the experimental reefs where fry odors were present than at those where such odors were absent. No clear-cut evidence of spawning was obtained, however, in either pool. Quantitative scoring and analysis of videotaped behaviors will be completed in 1982, and the attractant properties of fry odors will be further studied in simple Y-maze experiments.

Neal R. Foster
Daniel V. O'Connor
William H. Berlin
Paul E. Polanski

Growth, Food Consumption, and Conversion Efficiency of Lake Trout

To obtain data on growth and food conversion efficiency of large lake trout fed natural forage, we maintained subgroups of two year classes of Marquette Hatchery strain lake trout (1975 and 1977) on three rations (either ad libitum, 0.5%, or 0.25% of their wet body weight per day) at simulated lake temperatures for an entire year (all fish were maintained at 10° C during the final quarter). During the initial 6 months of the study, we fed smelt and alewives on alternate days. Trout fed either of the two restricted rations (0.5% or 0.25% of body weight per day) did not exhibit a clear-cut preference for either forage species. However, since both year classes of trout receiving the ad libitum ration showed a marked preference for smelt over alewives, the final half of the year-long experiment was modified to allow us to evaluate each forage species independently and eliminate the influence of food preference. During the third quarter of the experiment, the trout were switched from a diet consisting exclusively of smelt to one of alewives. The trout fed restricted rations did not decrease their food intake after this change in diet and continued to feed well on alewives. The trout fed ad libitum, however, showed a marked decrease in food consumption after the diet change. The apparent preference for smelt over alewives for fish fed ad libitum resembled that observed earlier when a mixed diet of alewives and smelt had been fed.

We completed data collection on food consumption and growth in early November. After we determine the caloric contents of the forage fish and lake trout used in the experiment, we will model the growth and conversion efficiency of the lake trout on the basis of caloric equivalents. This information is needed to complete a predator-prey model that will be used to predict the carrying capacity of the Great Lakes for lake trout.

Daniel V. O'Connor
Paul E. Polanski
William H. Berlin

Contaminant Dynamics

James G. Seelye, Project Leader

Surveillance of Contaminants in Great Lakes Fishes

> ***"While only eight compounds were identified in hatchery-reared lake trout, we identified 476 compounds in Great Lakes fish."***

Contamination by toxic substances such as mercury, DDT, and PCBs has restricted several fishery resources of the Great Lakes. Contaminants are also suspected of causing impaired reproduction of some Great Lakes fishes. To provide improved information on the status of known contaminants and early identification of new contaminants in fish of the Great Lakes, we continued to participate in a cooperative fish-contaminant surveillance program with the USEPA Central Regional Laboratory, Chicago, Illinois, in accordance with the International Joint Commission's Great Lakes Surveillance Plan. As part of the cooperative program, we reported on gas chromatography/mass spectrometry (GC/MS) analyses of adult lake trout or walleyes collected in 1977 from each of the Great Lakes and Lake St. Clair. Since the purpose of these analyses was to identify "new" or previously undetected environmental contaminants in the fish, we also analyzed adult hatchery-reared lake trout as a "control" consisting of fish raised in a relatively clean environment. At each sampling site, the 20 largest fish collected were composited into one sample. Contaminants were extracted, isolated from lipids, separated into two fractions, and analyzed by GC/MS. The technique used provided tentative identification (computer match) of compounds detected in the extracts. Final confirmation of the compound identities will ultimately require comparisons with chemical standards.

While only eight compounds were identified in hatchery-reared lake trout, we identified 476 compounds in Great Lakes fish. Four of the compounds present in hatchery-reared fish were also found in Great Lakes fish, but at higher concentrations. Of the 476 compounds detected in Great Lakes fish, 53 were halogenated hydrocarbons such as PCBs, DDT and metabolites, chlordane, and dieldrin plus several newly detected halogenated alkyls. Of these halogenated alkyls, 3-bromomethylcyclohexene was the most prevalent and found in samples from each of the Great Lakes. In addition to the halogenated hydrocarbons, we detected more than 15 different classes of compounds, including 5 polycyclic aromatic hydrocarbons. Over 150 compounds were alcohols, ethers, aldehydes, esters, or acids. Alkanes (straight or branched chain and cyclic) represented the largest group of compounds (>80) and were abundant in all samples. Walleyes from Lake St. Clair, followed by lake trout from Lake Michigan, contained the largest number of identified compounds (215 and 167, respectively.) Over half of the identified compounds are believed to be present as a result of human activity.

We collected supplemental samples of bloaters in fall 1980 in response to continued interagency concern about increased levels of dieldrin in bloaters from southeastern Lake Michigan, and to answer questions about possible decreased levels of PCBs in these same fish over the past 5 years. These fish were collected, processed, and analyzed in conformance with the design of our previous trend-monitoring program that included bloaters collected from 1969 to 1978. A total of 110 fish averaging 245 mm in length (9 mm shorter than fish collected in 1978) were composited into 11 samples and analyzed for PCBs, total DDT, and dieldrin. The results are given below. Average concentrations of all three contaminants decreased significantly relative to 1978 samples. This decrease represents the first significant decline of dieldrin concentrations that we have observed during the past 10 years. However, dieldrin concentrations are higher now than they were in the earlier 1970s. The results further extend the previously observed declines of DDT (95% since 1970) and PCBs (60% since 1974).

Robert J. Hesselberg
David A. Nortrup
James G. Seelye
Michael J. Mac

Table 8. Contaminant concentrations in bloaters from southeastern Lake Michigan.

Year	Number of fish	Average length (mm)	Total DDT µg/g	Dieldrin µg/g	Total PCBs µg/g
1978	100	254	0.81	0.55	3.08
1980	110	245	0.46	0.41	2.22

Differing Survival Rates of Lake Trout Eggs and Fry of the Upper Great Lakes as a Function of Their Origin and Rearing Environment

To study the possible association between contaminants and the survivability of lake trout eggs and fry, eggs and milt were stripped from spawning lake trout collected in fall 1980 from Lake Superior, Lake Huron, Lake Michigan, and from the Marquette State Fish Hatchery. Fertilized eggs from each source were then incubated at field sites in raw water from each of the three lakes at both ambient lake temperature and at a controlled temperature. In addition, eggs from the four sources were incubated in processed (filtered, chlorinated, and dechlorinated) Lake Michigan water and in the Laboratory's well water, both at a controlled temperature. After hatching, fry were reared for 139 days at each site.

Eggs from the four sources incubated at controlled temperature (about 6° C) were the first to complete hatching at the four sites. Egg mortality to hatch, as a percentage of fertilized eggs, was lowest (average for all egg sources) in Lake Huron water (9.6%), followed by processed Lake Michigan water (9.8%), Laboratory well water (12.9%), Lake Michigan water (17.5%), and Lake Superior water (20.0%). Eggs from Lake Superior had the lowest average mortality (average for all incubation sites)--only 6.7% of the fertilized eggs died before hatching. Mortality was 7.3% in Lake Huron eggs, 13% in hatchery eggs, and 28.8% in Lake Michigan eggs.

Eggs from the four sources were also incubated at ambient lake temperatures (0.3 to 12.2° C) at the three field sites. Egg mortality to hatching, as a percentage of fertilized eggs, was lowest (average for all egg sources) in Lake Huron water (8.3%) followed by Lake Superior water (15.5%) and Lake Michigan water (34.1%). In relation to source, eggs from Lake Superior again had the lowest average mortality (average for three incubation sites)--only 9.8% of the fertilized eggs died before hatching. Comparable mortality in Lake Huron eggs was 11.6%, 23.4% in hatchery eggs, and 32.4% in Lake Michigan eggs.

> ***"The poor performance by both eggs and fry of Lake Michigan origin may have been a function of their contaminant burden."***

Fry of eggs from Lake Michigan had a very high mortality rate through 139 days after hatching. At controlled temperatures, an average of 96.2% of the Lake Michigan fry died at all sites, while only 50.2% of the Lake Huron fry, 49% of the hatchery fry, and 39.7% of the Lake Superior fry died. Similarly, ambient temperatures Lake Michigan fry experienced an average of 95.6% mortality at all sites, compared with 60.3% for Lake Huron fry, 54.3% for hatchery fry, and 52.7% for Lake Superior fry.

The poor performance by both eggs and fry of Lake Michigan origin may have been a function of their contaminant burden. Contaminant analysis revealed that Lake Michigan eggs contained the highest levels of contaminants: 2.69 µg/g PCB, 1.27 µg/g total DDT, and 0.066 µg/g dieldrin. These concentrations are nearly an order of magnitude higher than the concentrations found in eggs from the other three sources: Lake Huron eggs contained 0.38 µg/g PCB, 0.21 µg/g total DDT, and 0.015 µg/g dieldrin; Lake Superior eggs contained 0.24 µg/g PCB, 0.15 µg/g total DDT, and 0.016 µg/g dieldrin; and hatchery eggs contained 0.10 µg/g PCB, 0.03 µg/g total DDT, and no detectable dieldrin.

Further contaminant analysis of fry sampled throughout the study is underway in order to evaluate more fully the possible association between contaminants and the poor survival of eggs and fry from Lake Michigan lake trout.

Michael J. Mac
Carol C. Edsall
James G. Seelye

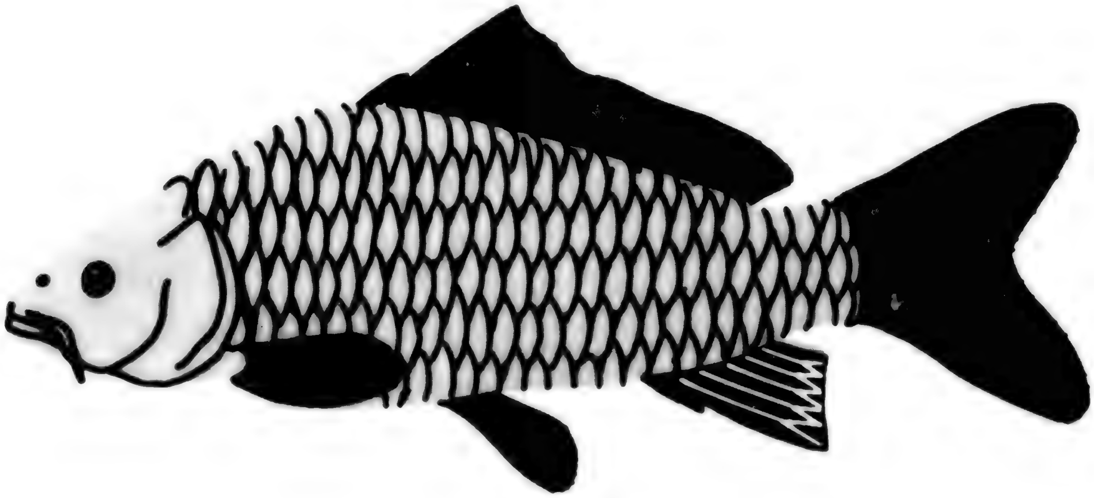
Bioaccumulation of Toxic Substances during Dredging

The annual movement of over 10 million cubic meters of sediment by dredging activities in the Great Lakes represents potential harm to the biota of the Great Lakes, not only due to the physical disruption of the habitat associated with the dredging operation, but also to the resuspension of sediments often contaminated with toxic organic and inorganic chemicals.

Under a cooperative agreement initiated with the USEPA, Great Lakes National Program Office, we conducted a literature review on the effects of dredging and dredged material disposal on aquatic life. Current regulations regarding approval for dredging activities require measurement of contaminant levels in the sediment and comparison of those levels with established criteria. Although these criteria need to be correlated with bioavailability and toxic effects of the chemicals, to date, no broadly applicable correlations have been defined. This lack of a definable relationship between levels of chemicals in the sediment and the bioavailability of these chemicals has led to the proposal that bioassessment tests (including toxicity and bioaccumulation) be conducted for all proposed dredging operations, a procedure currently being used for ocean dumping of dredged material. Laboratory studies have shown the potential bioavailability of both organic and inorganic contaminants from resuspended sediments, but the procedures used for bioaccumulation studies vary widely and little information is available relating the accumulation of contaminants by organisms to overall effects on the ecosystem.

Three computer-assisted literature searches were completed on the following topics: (1) fish movement as affected by dredging and dredged material disposal, (2) effects of contaminated sediments on freshwater organisms, and (3) bioassessment of sediment quality. Twelve data bases were searched for each of these topics. We examined over 1000 references and abstracted over 100 of these for inclusion into an annotated bibliography. This bibliography, along with a review of research needs and a proposal for specific research in the Great Lakes, will be provided to EPA in accordance with the cooperative agreement.

James G. Seelye
Michael J. Mac
Carol C. Edsall



Contaminant Toxicology

Dora R. Passino, Project Leader

Toxicological Evaluation of Recently Identified Contaminants in the Great Lakes

To evaluate initially the potential harmfulness of 476 recently identified organic compounds in fish of the Great Lakes, we reviewed the published literature and unpublished information on the toxicity, bioaccumulation, environmental occurrence, and potential sources of the listed compounds. Information on toxicity and bioaccumulation of 40 of the better-known contaminants was obtained by manual searches of journals, handbooks, compendia, and by interactive searches of the Information System for Hazardous Organics in the Water Environment (Duluth); Chemical Abstracts; Biological Abstracts; Aquatic Sciences and Fisheries Abstracts; and IRL Life Sciences Collector (Ecology and Toxicology Abstracts). In an attempt to determine which of the compounds have primarily anthropogenic origins as opposed to natural origins, we compared the list of compounds with the Toxic Substances Control Act (TSCA) list, the Industrial Chemical Survey of 1980 of the New York State Department of Environmental Conservation, the EPA list of 129 priority pollutants, and with other lists of pollutants. We also considered possible physical, chemical, or biological alteration of anthropogenic compounds in the environment and alteration resulting from metabolism of these compounds by fish.

The compounds were categorized into functional groups and ranked by category based on research and regulatory priority. The compounds with high known toxicity or bioaccumulation ranked at the top of the priority listing. These and other compounds that occurred frequently or in high concentrations in the fish and whose structure indicated likely toxicity or bioaccumulation were ranked in descending order as follows: complex, chlorinated polyaromatic hydrocarbons (e.g., endrin); arene halides (e.g., PCBs); chlorinated camphenes (toxaphene); alkyl halides (e.g., 3-chloro-1-propynylcyclohexane); polyaromatic hydrocarbons (PAHs) and reduced derivatives; complex PAHs; phthalate esters; heterocyclic compounds; monocyclic terpenes; sulfur containing compounds; phenols; and cyclic ethers. Many of the compounds that ranked below these (such as fatty acids, alcohols, and alkanes) are probably natural components of wild fish. The contaminants that rank high in the above listing, as well as fractionated extracts of fish samples, will be tested in short-term bioassays.

The large number of compounds requiring evaluation necessitates bioassay procedures that are more rapid and use smaller test volumes than those using fish as the test organism. Therefore, these tests will be conducted initially with Great Lakes crustacea to identify better the contaminants requiring immediate regulatory attention or expanded research and monitoring efforts. We have been comparing the utility of daphnids and Bosmina longirostris as alternative test species, using p,p'DDT as a reference toxicant and evaluating the influence of different diluent waters on resulting toxicity values (measured as immobilization). The results of the static tests completed are shown in Table 9.

Table 9. Acute toxicity values (48-h EC50 values, $\bar{x} \pm SE$, µg/l p,p'DDT).

	Softened Well Water 130[a]	Reconstituted Hard Water[b] 170[a]	Reconstituted Soft Water[b] 40[a]
Bosmina longirostris	2.52 ± 1.07	0.63 ± 0.03	---
Daphnia pulex	2.70 ± 0.24	---	2.35 ± 0.12
Daphnia magna	---	---	2.63 ± 0.63

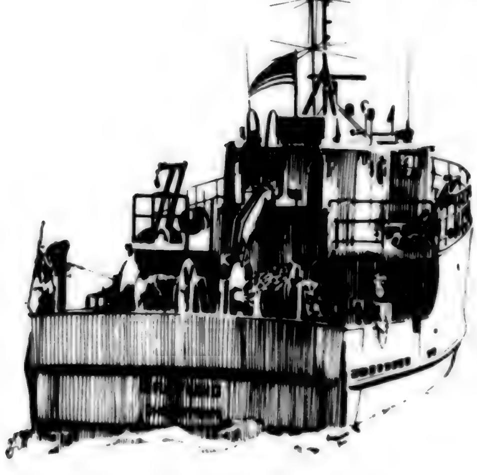
[a] Total hardness as mg/l $CaCO_3$.
[b] Prepared by adding salts to deionized water.

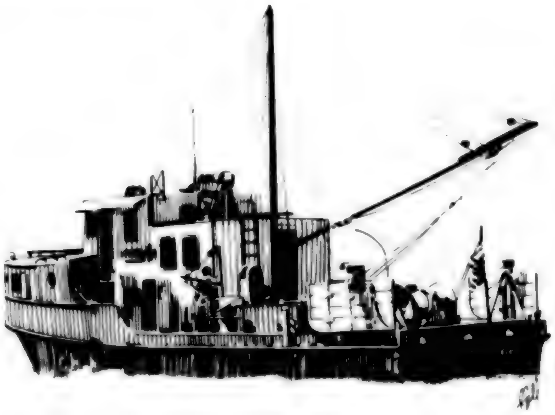
These results demonstrate the greater sensitivity of Bosmina and improved reproducibility of results in reconstituted hard water. Since none of these three species thrive in reconstituted soft water, we recommend use of reconstituted hard water for culturing and testing them.

We developed a continuous culture system that reliably produces large numbers of healthy Bosmina neonates. These are automatically separated from their mothers by a process which relies upon the positive phototoxic response of Bosmina to attract them through sieves sized such that only the smaller neonates are admitted. We can handle the Bosmina with greater ease and feel more assured of accurate counts, by using a semi-automated counting and transfer system, in which the neonates individually pass before a photocell. The flow-through testing system developed for Bosmina and daphnids will enable us to perform screening tests on a large number of contaminants and will require only minute amounts of each compound.

Dora R. May Passino
Alexander Novak
K. Cliff Chambers

Program Support





Vessel Management Services

Alfred Larsen, Chief

Vessel Operations, Rehabilitation, Maintenance, and Safety

Budget restraints required extending furloughs for seasonal vessel personnel and sharply reducing operating schedules during the field season.

The research vessels Cisco and Grayling were drydocked for the regular 3-year inspection, maintenance and painting of their hulls, and other servicing requirements. The Cisco's propulsion engine was equipped with an improved engine lubricating system and the vessel's standby generator was overhauled. The radar system for R/V Musky II was reconditioned. The Kaho's electrical panels and the Oswego Vessel Base dock's electrical power hookup were rewired to improve electrical supplies to the vessel during tie-up.

Additional vessel and small craft equipment or maintenance projects completed during the year included purchasing and installing Loran C navigation computers aboard all the large vessels. This equipment permits precise navigation of the vessels and location of sampling stations with a degree of accuracy never before possible.

All the large vessels have been supplied with Coast Guard approved abandon ship exposure (survival) suits, and crews have been trained in their use.

All large vessels and small craft were found to be in safe and satisfactory operating conditon by the U.S. Coast Guard in pre-season safety inspections. Minor deficiencies cited in several cases were corrected.

An illustrated brochure describing the Laboratory's large vessel research fleet, along with its operation and management, was published.

Biometrics and Computer Services

Paul M. Haack, Chief

Assistance in Applied Statistics

Sample data, regardless how large the amount, would be meaningless without statistical analysis. The Biometrics and Computer Services Unit's major task is to advise and assist staff scientists in developing appropriate techniques for sampling, experimentation, analysis of data, and interpretation of findings. Without computer assistance, it would be almost impossible to perform the increasingly sophisticated and complex analyses used today.

We used a number of statistical programs in a variety of applications. MIDAS, available through the University of Michigan MTS system, is an especially versatile and useful tool for analyses of variance and covariance, regressions, scatter plots, and many other types of data treatment used by almost all research work units. COVAR was used to relate the distribution of forage fish from survey trawl catches to water temperature, rainfall, and wind condition over 20 years, and to relate the number of insects to surface area of macrophytes by season and location. PROBIT helped us analyze individual and combined experiments to determine effects of DDT on test populations of Bosmina longirostris, Daphnia pulex, and D. magna. DMBV8 made it possible to compare logarithms of CPE for five fish species in western Lake Erie by season, time, depth, and year to develop strata for biomass estimates.

The range of applied statistical assistance we provided is illustrated by the following examples of the year's projects: Development of an approximation for unequal replicates in Duncan's k-ratio t-test; advice on the derivation of $(pq/2N)^{0.5}$ for testing genetic variability; estimates of sample size for age-on-length data; application of Ricker's stock-recruitment model for two data sets of alewives in Lake Michigan; estimes of Van Bertalanffy (growth) parameters for smelt in three areas of Lake Michigan; computation of biomass estimates with confidence limits for freshwater drum in the western basin of Lake Erie: advice on the statistical analysis and programming for work on the population dynamics of six prey species in six areas of Lake Superior over 3 years; chi-square applications to compare effects of various contaminants on Bosmina spp.; development of the statistical analyses and programming for a study of lake trout wounding by sea lamprey; and computation of means, variances, standard deviations, and sample sizes for each mesh size by species, season, and year for a technical consultant to the Sault Ste. Marie Tribe of Chippewa Indians.

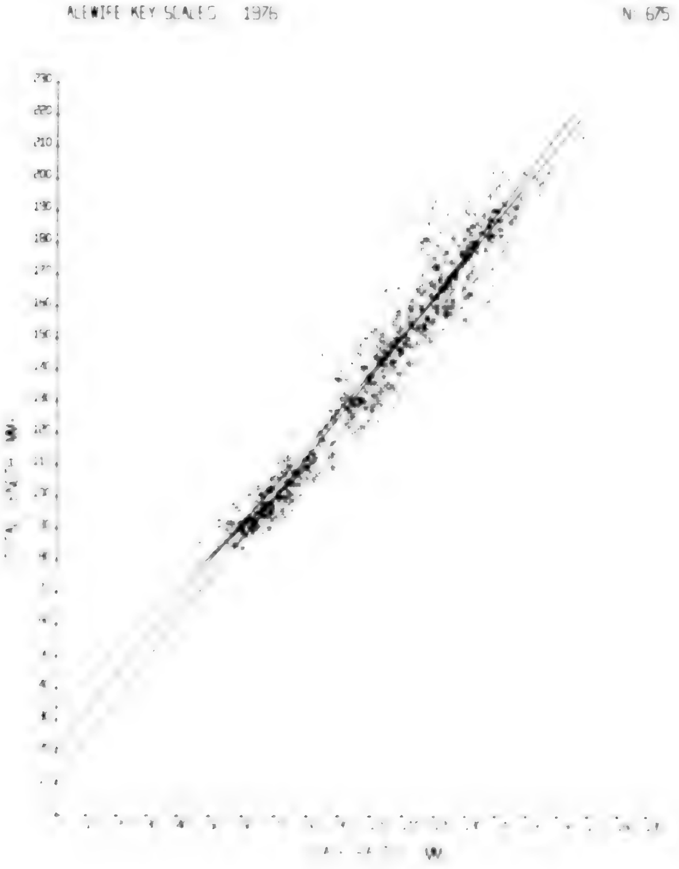
Computer Programming and Data Processing

The computer is a valuable tool for producing generalized, periodic tables and graphs to summarize large amounts of data for ready examination and analysis. It also performs the important function of editing raw data to detect invalid or questionable field-data entries. Unit keypunchers are trained not only to punch the data submitted for processing, but also to run and interpret various edit programs to ensure the accuracy of incoming data.

At regular intervals throughout the year, programs are run summarizing survey (trawl and gillnet) catches, length-frequencies. length-weight relations, age and length distributions, back-calculated lengths and increments of growth, catch-per-unit effort (CPE) statistics, and biomass estimates. Other programs tabulate abundance of benthos, phytoplankton, zooplankton and macrophytes, and produce histograms of length-frequency, CPE, and biomass of several fish species.

Requests are also filled for various commercial catch (COMCAT) reports. This year, our COMCAT system of programs was upgraded to meet several user requests. This upgrading included developing a capability for converting dressed to round weight for better consistency in reporting fish landings.

The maintenance and modification of existing computer programs, along with the development of new ones, is an ongoing task necessitated by constantly changing and expanding needs. We routinely save and back-up all data on magnetic tape, and periodically update or correct data files as necessary.



Body length-scale diameter relationships of adult male, adult female, and yearling alewives in Lake Huron. (CalComp Plotter)

Fish-Holding and Aquarial Services

William H. Berlin, Fishery Biologist

A "living stream" fish-holding unit (an oblong, glass-sided tank with three compartments) was fabricated to facilitate side-by-side comparisons of color patterns and behavior of two-year-old lake trout of siscowet, Gull Island Shoal, and Marquette Hatchery strains. We also set up a cylindrical, glass-sided tank (700-liter capacity) with external drain and false, flow-through bottom which was covered with pea gravel and cobble. This was used for studying and recording behavior of young-of-the-year and adult lake trout in the presence of a simulated cobble and gravel-covered lake bottom.

Early in 1981, extensive improvements were completed on our diatomaceous earth filtration system, including replacement of several filter element sleeves. In October, a high capacity supplemental filtration system was installed in the water supply line to the two behavior observation polls to reduce water turbidity associated with periodic maintenance of the diatomaceous earth filters. Also, rehabilitation of well no. 1 (drilled in 1966) is nearing completion; a new well screen and 10-hp pump are major components of the restoration. The pumps of wells 1 and 3 are connected to emergency power and are plumbed so that either well can function as an automatic standby in an emergency.

A massive die-off of laboratory fish stocks occurred during mid-December in apparent association with installation of new filter medium (manganese greensand) in all three iron filters. We have not yet determined the specific cause of the mortality; however, chemical tests and bioassays of water collected from various points in the water system indicate that a faulty value on the iron filters allowed chlorinated city water into the processed water system.

Neil Foster

Fish-rearing tanks.

Space, equipment, processed water, and limited technical assistance were provided to two graduate students from the University of Michigan: A doctoral candidate from the School of Public Health, Department of Environmental and Industrial Health studying the uptake and physiological effects of an organochlorine contaminant on adult rainbow trout; and as master's degree candidate from the School of Natural Resources studying the effects of PCB (Aroclor 1254) exposure and incubation temperature on the fatty acid composition of various lipid classes in rainbow trout eggs and sac fry. We also held 86 spawning-run sea lampreys for pickup by personnel of the Monell Chemical Senses Center, who subsequently transported the lampreys to their laboratory in Philadelphia for studies on sea lamprey pheromones.

Library and Information Services

Cynthia A. McCauley, Librarian

As the quantity of information available on-line via computer terminal grows, so grows the capability of the Laboratory's Van Oosten Memorial Library. Access to the Dialog System puts over 125 data bases at our fingertips, and 1981 brought the library its own computer terminal with the capability to transmit and print up to 120 characters per second. Searches can now be performed efficiently and quickly--within minutes--in the library.

The reprint collection was closed, and few new books were purchased because of staff and budget constraints. The high inflation rates of journal subscriptions and book prices seriously hamper our ability to continue to build the library collection, a problem common to many libraries. Increasing interlibrary loan activity during 1981 reflected this situation. On the OCLC system, the library borrowed 71 items and lent 21. Using the American Library Association Interlibrary Loan Request, it borrowed or received photocopies of 96 items and lent or sent photocopies of 192 items. Items borrowed from the University of Michigan numbered 32, requests for papers from authors, 327.

Administrative Services

Judy L. Gunter, Administrative Officer

The Laboratory's administrative staff served the diverse needs of 67 full-time and 19 other-category employees stationed in Ann Arbor and at five satellite facilities. It assisted in developing and managing the Laboratory's complicated budget; processed a myriad of personnel actions; completed over 1,000 financial transactions; and prepared numerous reports throughout the year dealing with such matters as Equal Opportunity, personnel, property management and accountability, training, vehicle use, travel, safety, and procurement.

In cooperation with Service engineering and contracting functions, we have completed installation of ground-fault-circuit-interruptor protection, modified the Ann Arbor facility's air-handling system, took occupancy of a new service-storage building, and began repair of a major water-supply well.

Technical Communications

Eric J. Meves, Editor

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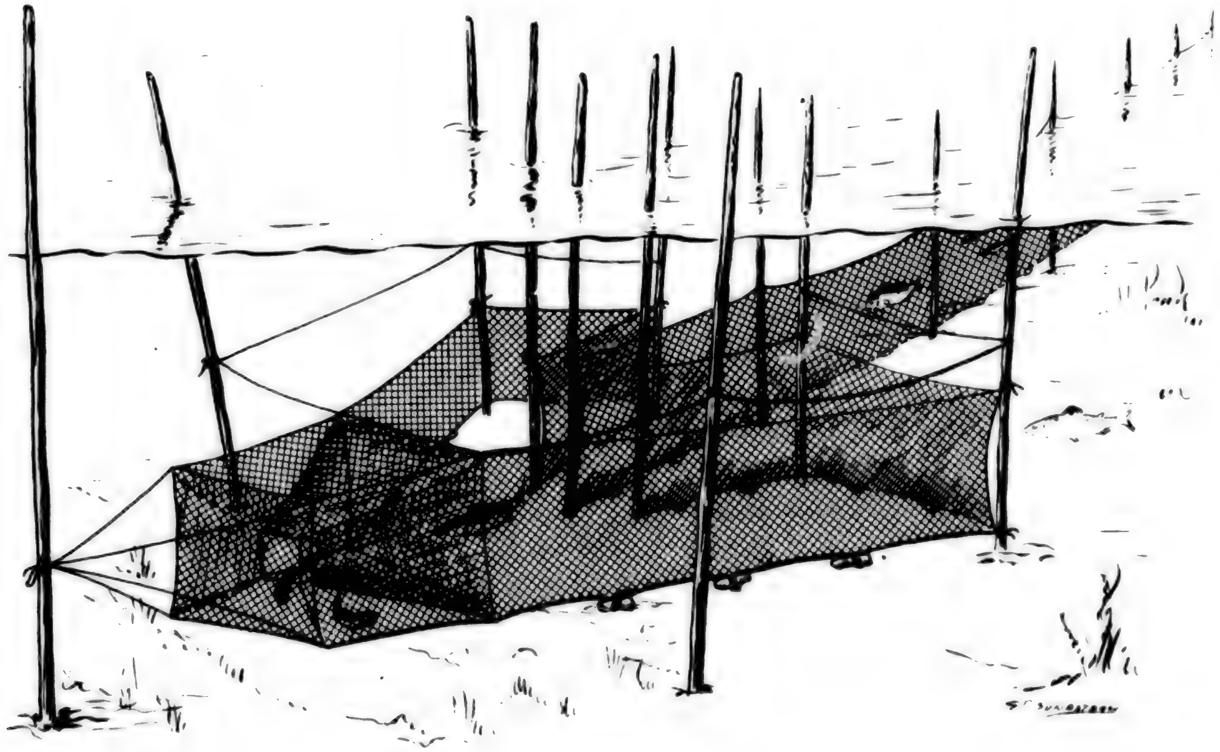

Pound Net

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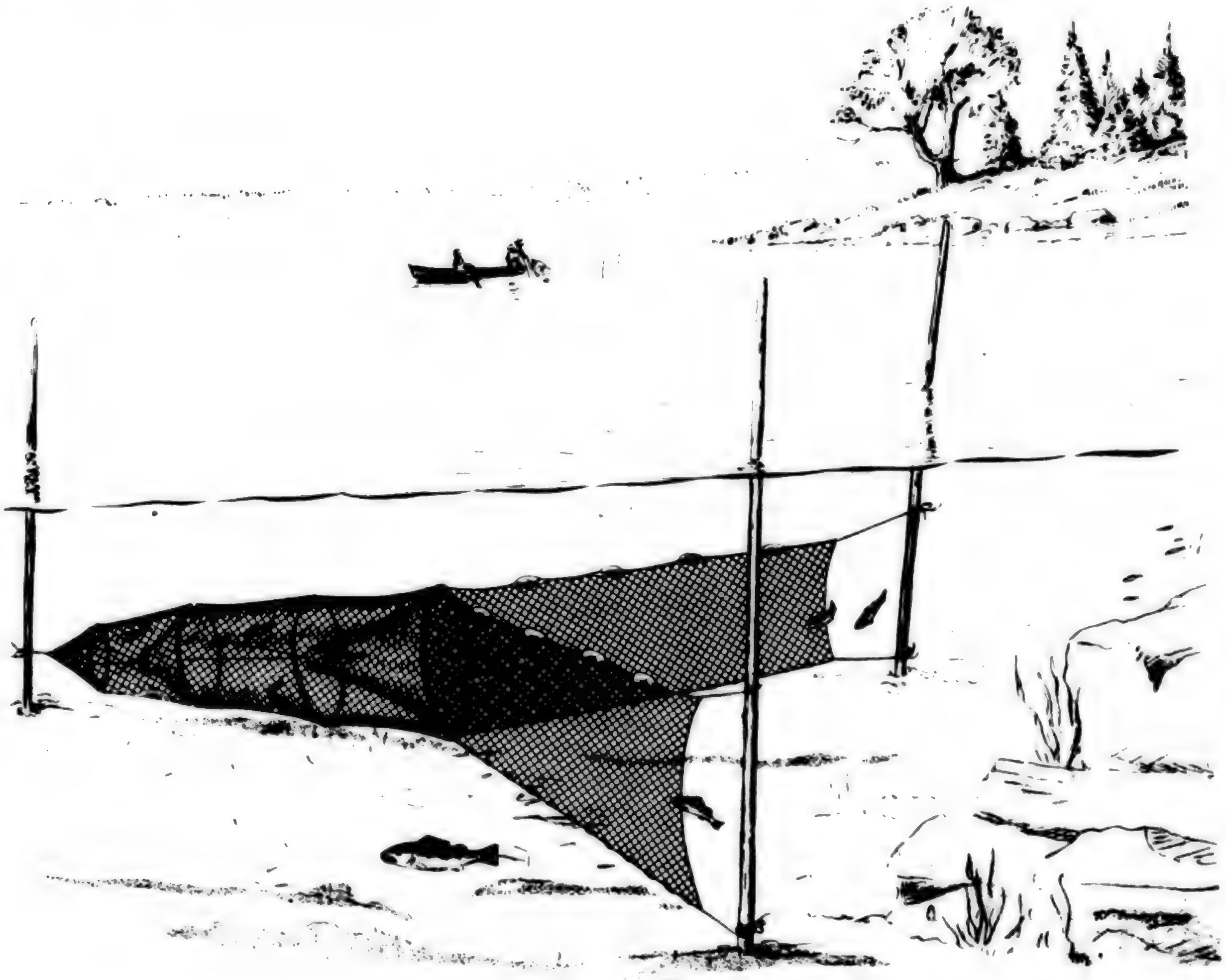

Fyke Net

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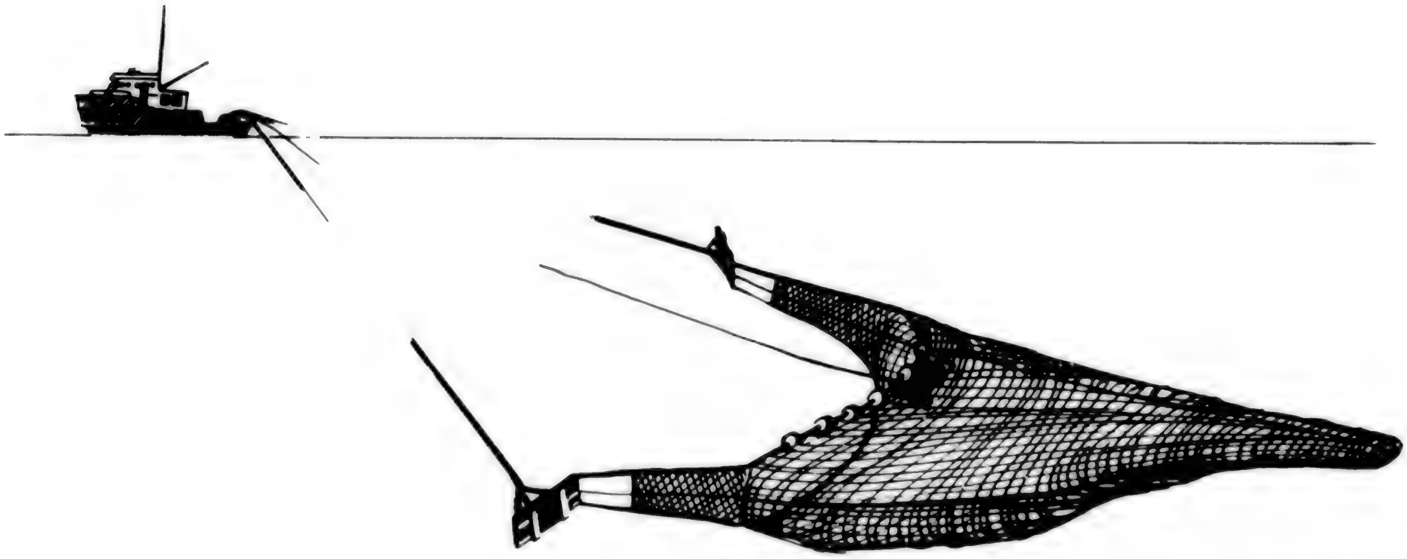

Trawling

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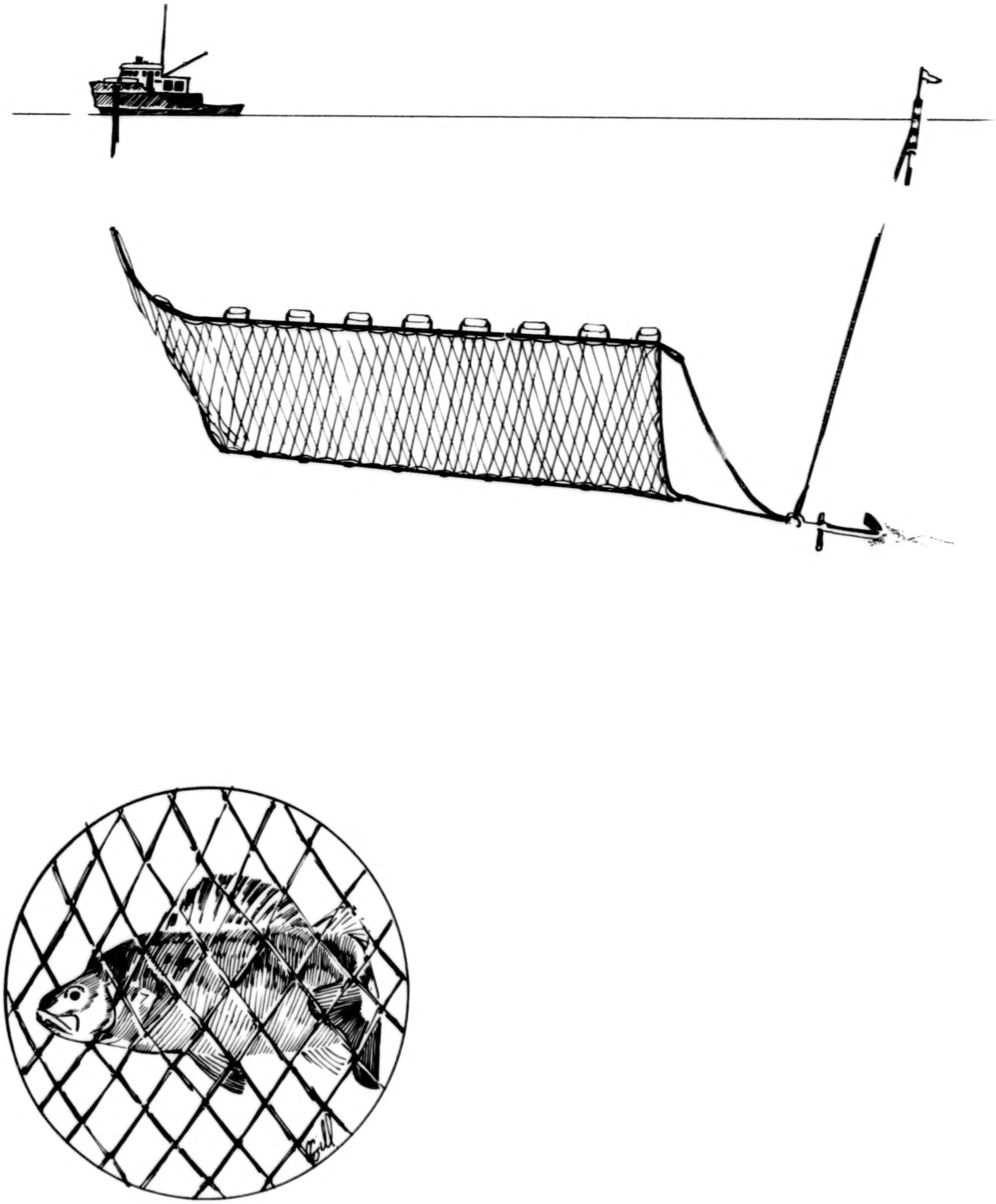

Gillnet

Kristine Moore Meves

END

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